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ABSTRACT

The focus of this document is upon zetetics, the science of research and artistic activity, and its role: to study the origin, growth, and transitions of human knowledge as a whole. The choice and allocation of subject matter within the curriculum is one of the central domains of expertise required of the general curriculum specialist. No matter how curriculum content is conceived or incorporated into the curriculum, the body of accumulated knowledge found in the established disciplines and fields of study associated with formal inquiry needs to be explored. In a comprehensive attempt to identify and order the "totality of recorded systematized knowledge," this document lays out 12 distinct areas in which research and creative activity have been built up and made available. Detailed discussions are presented on the following topics: (1) Zetegeny--the emergence and growth of the arts and sciences as an evolutionary process; (2) Taxilogy--developing an inventory of the zetetic system of knowledge and methods of detecting gaps in knowledge; (3) Problematology--the selection and formulation of problems; (4) Zetesis--the ability needed to do research and creative activities; and (5) General Methodology--the methods of research and terminology common to all disciplines. (JD)

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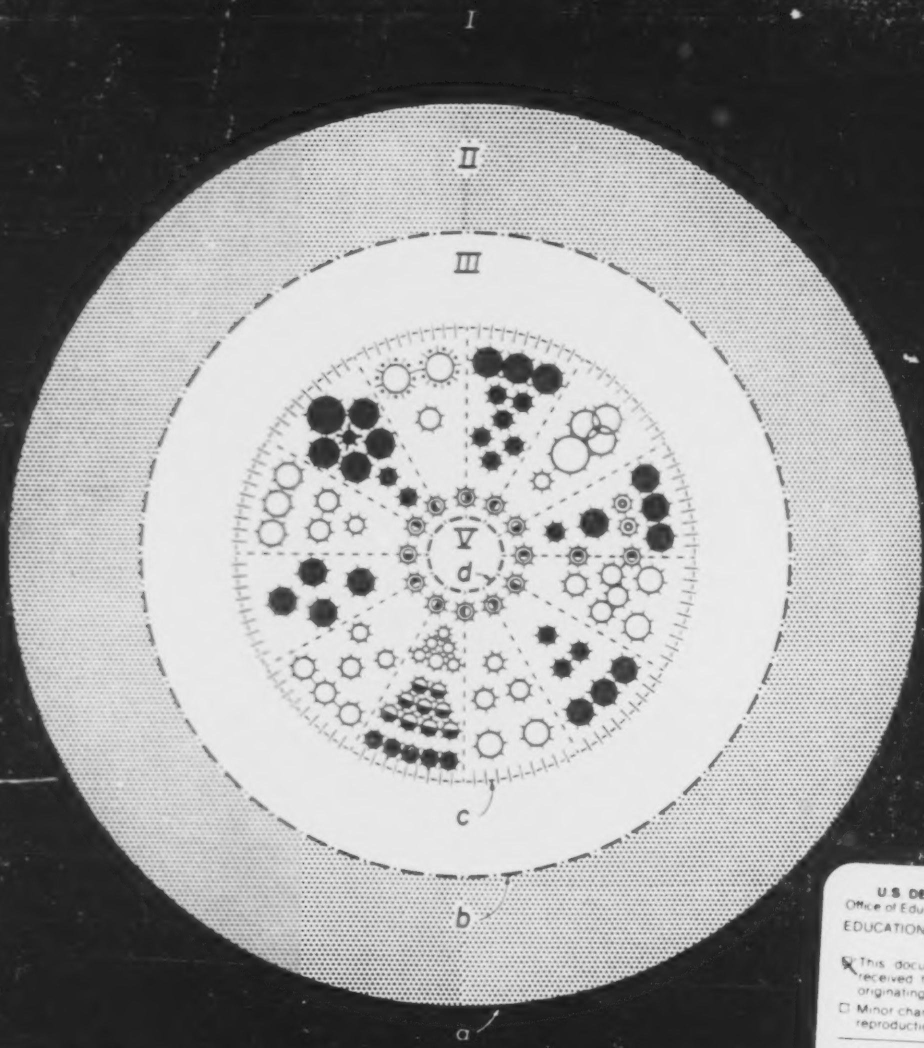

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Outline of Zetetics

A Study of Research and Artistic Activity

by Joseph T. Tykociner

SF 030305

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1988 Foreword

One of the consequences of Sputnik (1957) was a wave of educational reform, or more precisely, a wave of rhetoric about such reform. One result of the rhetoric was the development of new curricula in physics, mathematics, chemistry and biology by real scientists rather than educationists. The scientists would create curricula that would embody the structure of the science, especially its conceptual structure, rather than the problems of motivation, individual differences and other psychological and social concerns of the educationists. The search for and the application of structure to curricula was to spread to the social science, linguistics, and even to the fine arts

If there is an ironic flavor to these comments, it is not because the emphasis on the structure of the disciplines was misguided. Good mathematics, good physics, good chemistry and good school disciplines of any kind owe their validity to the guilds of scholars devoted to their development and constant criticism. It is rather to note that while the new curricula had great influence on textbooks it has rather less impact on the great mass of public school classrooms that had to rely on cadres of teachers who were not brought up on the new mathematics, and who conducted classes in schools that did not isolate the gifted for instruction.

Nevertheless, Jerome Bruner and others realized that the structure of knowledge was a key and perhaps the master key to formal schooling. For the best psychology of learning and social sensitivity are no substitute for the integrity of subject matter. Educators, therefore, joined the scientists in the search for structure, and it is not surprising that the Fifth Annual Phi Delta Kappa Symposium on Educational Research was entitled "Education and the Structure of Knowledge."[1]

The symposium was planned by B. Othanel Smith and was held at the University of Illinois at Urbana in 1963. Among the papers invited for the occasion was one entitled "Zetetics and the Structure of Knowledge" by Professor Joseph T. Tykociner of the University of Illinois Department of Electrical Engineering.[2]

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[1] Education and the Structure of Knowledge, Stanley Elam, Editor. Chicago: Rand McNally, 1964.

According to Tykociner, the sciences, humanities, and engineering were being regarded as separate islands, each with its own cadre of scholars, researchers, teachers, and practitioners. It is the role of zetetics, the science of research and artistic activity, to study human knowledge as a whole: its origin, growth and transitions. Especially important for the enterprise is to discover the bridges between disciplines that seem to be unconnected.

To carry out this ambitious program, Tykociner developed, with the help of Greek roots, an extensive vocabulary including such terms as zetezsis, zetegency, taxilogy, problematology, exeligmology, etc., as well as a detailed map of the several areas of knowledge, their functions, and their interconnections. This work was published under the title Research as a Science--Zetetics in 1959, and a somewhat revised and expanded version appeared as The Outline of Zetetics, A Study of Research and Artistic Activity in 1966. Both were published by the Electrical Engineering Department of the University in typewritten form.

The active career of Professor Tykociner as engineer and scientist spanned more than 70 years. The first 50 years were spent mainly in the physical sciences, beginning as a pioneer in the field of radio. He is probably best known for his invention of sound-on-film, successfully demonstrated at the University of Illinois in 1922. The last score of years were devoted to the study and teaching of zetetics. His dream of integrating all research and knowledge in the sciences and humanities led to the establishment of the Tykociner Memorial Lectures at the University of Illinois.[3]

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[2] Op. cit., pp. 120-147.

[3] The first lecture was given by Dennis Gabor, "The Scientist in the New Society," 1972; the second, "The Divorce Between the Sciences and the Humanities," by Sir Isaiah Berlin, 1974; the third by Leon N. Cooper, "Science and Human Experience," 1976; the fourth by Sol Spiegelman, "The I and We of Science," 1978; the fifth by Freeman J. Dyson, "Quick is Beautiful," 1981; the sixth by Sir Zelman Cowan, "Contemporary Tasks for the Law," 1983; and the seventh by Richard Rorty, "The Contingency of Selfhood," 1986.

When my colleagues, B. Othanel Smith and Joe R. Burnett, and I set out to do a book on the curriculum in the early 60s, we were confronted with the perduring and obstinate problem of how the school can produce excellence without snobs and equality without slobs. Then, as now, a clamor arose for excellence in the schools, for curricula that would challenge the gifted to lead the nation into the scientifico-technico future, albeit at that time the Japanese had not yet demonstrated how it was to be done. Clearly, the school had to develop a curriculum that within the constraints of resources and time could combine the insights of the humanities as well as of the sciences. It occurred to us that the Tykociner map provided a valuable guide to the construction of a curriculum that could make strong claim to being the same for all yet would provide clues to methods of teaching that would take into account individual differences.[4]

A glance at the design of our curriculum shows the influence of the Tykociner classifications. We decided that the general education requirements would include Symbolics of Information, viz., language and mathematics, to which one might add the symbolic skills of aesthetic perception; Basic concepts from biology, chemistry, and physics; Developmental Studies of the cosmos, institutions, and culture; Value Exemplars from art, literature, philosophy and religion; and Social problems of exercises in considering molar personal and social problems.[5] This design gave us a framework for selection and evaluation of content and methodology. We did not copy the Tykociner classifications or attempt to delve into their sophisticated theoretical constructs, but they provided us with a highly rational and sophisticated store of resources for making educational decisions.

The specification of the three developmental strands came pretty much from the Tykociner map. It served not only as source of nomenclature, but more importantly as a check on completeness and logical cogency. It helped us distinguish between the various disciplines as subjects of direct instruction and the activities wherein the students used the resources of the disciplines to perfect their skills in problem-solving, especially of what we dubbed "molar" problems.

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[4] Professor Tykociner, for many years, taught a course "Research as a science" in the Electrical Engineering Department.

[5] Democracy and Excellence in American Secondary Education, Chicago: Rand McNally, 1976, p. 160.

Understandably, the elimination of formal study of history, geography, civics and foreign languages as such from the general curriculum were not received with unqualified enthusiasm, for these subjects are valid targets for school instruction. However, one might legitimately ask whether these subjects were essential to general education or should be more properly and logically included under requirements for various strands of vocational and prevocational training. Which foreign language, for example, should be required of all? And do courses required for entrance into college all automatically qualify as general education? These questions plunge the curriculum designer into problems that occupy the attention of philosophers of education, who, in turn, must master the structure of disciplines that are relevant to them. The nature of the good life in a culture that is regulated by good institutions may not always ingress the curriculum explicitly, but they hover behind every curriculum decision.

This strategy, however, entailed a careful conversion of formal historical resources and the concepts of a whole array of what Tykociner lists as "sociological sciences, sciences related to sustaining life, regulative and disseminative sciences." The process of selection and their embodiment in a curriculum is a challenge to the whole panoply of research we call "educational"--curriculum design, school administration, learning theory, and evaluation, let alone textbook publication.

In a phrase, we can think of a field called "educational zetetics" that studies systematically the translation of human experience into teachable programs under the fiscal, social and political constraints of a culture. That we are far from having such a science, despite the volume of educational research, may perhaps serve as an incentive to develop one. In the table of contents Tykociner promises that Chapter VIII, "Education for Zetises, the Activities Required by Zetetics," Chapter IX, "Environmental Conditions and Incentives," and Chapter X on "Research Centers" would "be added in a later addition."

The arts are not neglected in the zetetic map of human activity. The citations in the index include: art criticism, artistic creation, arts as communication, as basic sciences, functions, growth prospects, links with other areas, place in knowledge systems and the uniqueness of works of art. Related to the arts are what Tykociner called the "aspirational sciences," which embrace a large variety of ideological patterns reflecting the highest human aspirations and including all the theologies" (p. 63). Aspirational sciences belong to the larger group of integrative sciences.

At no time has the study of research into the nature of knowledge, its character and uses been more functional than it will be in the coming decade and the century that it will introduce. The speed with which abstract knowledge is transformed into technological instruments and political policy is as impressive as it is frightening.

It is, in short, a propitious time to examine once more the insights of zetetics.

—H. S. Broudy

University of Illinois

1988 Introduction

For those whose specialty in education focuses upon curriculum planning and program development, the issue of what substantive ideas should be included is a perennial one. Despite the fact that there are always pressures to teach particular content and doctrines coming from groups both inside and outside of the educational system, the ultimate decision about what shall constitute the curriculum in a given situation is likely to rest with those most knowledgeable about the options concerning relevant subject matter related to the goals and objectives set for the particular program or school.

And who is most knowledgeable about such options? Those who have studied the issues most thoroughly, have a firm grasp of the historical impact of various arrays and patterns of content as they have been structured and incorporated into the curriculums of the past, and have a sense of the significance of leaving certain things out of the curriculum as well as of the appropriateness of including certain other things in the curriculum. This issue of the choice and allocation of subject matter within the curriculum is, therefore, one of the central domains of expertise required of the general curriculum specialist in education and one of no small value for teachers, professors, and other educators concerned with a more limited range of content choices than those pertaining to the whole curriculum.

Knowledgeable curriculum specialists have no special insights that provide them with infallible choices on the matter of what content a given curriculum should include. Substantive content can take many forms in curriculum. It can range all the way from casual information to highly structured disciplined knowledge. It can focus on human or life processes or on formal cultural content. It can be transmitted as established truth or practice, or it can be prompted by questions to which students must determine the best answers anew in each generation. Or it can be a combination of these. Hard choices have to be made in every situation. Curriculum specialists can tell you, however, that no matter how curriculum content is conceived or incorporated into the curriculum, certain sources need to be explored if one is to become aware of the many options that exist and that should be considered.

Conventional wisdom suggests that ideas and values fundamental to the society within which the curriculum being planned resides is one of these sources of substantive content. Another is the human capabilities, personal and social, that are understood to be inherent in all human beings. Another is the body of accumulated knowledge that is found in the established disciplines and fields of study associated with formal inquiry. There may be other sources as well, but it is to this third source of curriculum content options that Tykociner's Outline of Zetetics makes a significant contribution--to the realm of understanding research knowledge and inquiry.

No knowledgeable curriculum specialist can afford to be uninformed about this major source of options for selecting substantive curriculum content. Tykociner's work can assist in making us conscious of the scope and types of formal knowledge that have been generated by scholars. His book is essentially a comprehensive guide to all existing knowledge and to the principles of its generating and organization.

A brief examination of the chart appearing on page 45 in Figure 4.3 will give a helpful preview of Tykociner's "Zetetics and the Zetetic System of Knowledge," the focus of his entire book. In what may be the most comprehensive attempt to identify and order the "totality of recorded systematized knowledge," Tykociner lays out twelve distinct areas in which research and creative activity have been built up and made available in a group of closely related disciplines or fields of study. Between each area of knowledge and its closest neighbor in each direction is a kind of hybrid field of study that combines characteristics and purposes of areas in both directions. Tykociner describes the common relationships among disciplines that are grouped together in a single area, distinguishes them internally from one another, and notes the links between each pair of areas of knowledge around the circle of twelve. Tykociner does this explicitly and thoroughly, but he also does much more in this book.

Since the book focuses upon Zetetics as a special family of disciplines concerned with methods of research and artistic production and several related matters, treated in general terms, rather than in terms appropriate to a specific discipline, Area A_{II} on the chart becomes the subject matter of Tykociner's book. There is a chapter on Zetegeny (on the emergency and growth of the arts and sciences as an evolutionary process), a chapter on Taxilogy (concerned with an inventory of the zetetic system of knowledge and methods of detecting gaps in it), a chapter on Problematology (on the selection and formulation of problems), a chapter on Zetesis (on the abilities needed to do research and creative activities), and a chapter on General Methodology (methods of research and terminology common to all the disciplines). Work on three other related topics were not completed by Tykociner before his death, and so they are not included in this book.

The careful ordering and reasoning that Tykociner presents stands marvelously enlightening and compelling for those not familiar with the entire zetetic system of knowledge. No attempt has been made in presenting this new edition to establish or to critique its authoritativeness as an effort in research in this very specialized field. In fact, there are few scholars who have ever attempted this sort of task, and each of them has conceptualized and rationalized the system of knowledge in a unique way, as would be expected. There is no "right" way, and so Tykociner's systematization is offered as he articulated it for whatever value it may have. The real question is how such a scheme may be used in resolving practical issues of curriculum content selection and organization.

Three books, written in the 1960s by curriculum scholars, explored the same conceptual or taxilogical (Tykociner's term) territory as Tykociner did. They were written, of course, from the vantage point of the needs of the curriculum planner and program developer and did not explore the zetetic questions as fully as Tykociner did. Arthur J. King, Jr., and John A. Brownell, for instance, in a book titled _The Curriculum and the Disciplines of Knowledge: A Theory of Curriculum Practice_ (Wiley, 1966; Krieger, 1976), trace the development, differentiation, and classification of the disciplines from ancient to modern times as well as identify what characterizes disciplines in general. Joseph J. Schwab treated the problem of the organization of the disciplines, their internal substantive and syntactical structures, and the issues involved in their selective use in curriculum; this work appeared in a book edited by Stanley Elam titled, _Education and the Structure of Knowledge_ (Rand McNally, 1964). Tykociner contributed to this book as well. So did Philip H. Phenix. Philip H. Phenix, in _Realms of Meaning: A Philosophy of the Curriculum for General Education_ (McGraw-Hill, 1964), described 20 major disciplines, organized them in six distinct realms, and interpreted their distinctive substances and related features in preparation for offering a model curriculum of his own for general education. No similar work by curriculum scholars has been written since the 1960s. By bringing Tykociner's work back to the attention of curriculum planners and program designers in the 1980s and 1990s, the problems and issues inherent in curriculum content selection and organization may be reexamined once again in light of the nature and status of contemporary systematized knowledge.

Knowing as much as possible about this key source of substantive content for curriculum should contribute to making better choices. Tykociner's book does not, of course, provide all one needs to know about knowledge in order to make sound curriculum decisions. Many elements besides systematic knowledge also must be considered. But detailed understanding of each of the disciplines that might be considered a contributor, in some form, to curriculum content is also necessary. Curriculum specialists who have studied the pertinent disciplines thoroughly will need to add their expertise to that of the experts in zetetics.

With these kinds of expertise at hand, curriculum specialists may find it easier to deal with practical questions, related to incorporating knowledge into the content of the curriculum, such as these:

1. If we exclude knowledge from Area X or Discipline Y from the curriculum, will this affect understanding of another area or discipline?
2. Would it be wise to combine knowledge from regulative, hylenergetics, biological, and sociological disciplines into one course or strand?
3. Are the research tools used in two or more disciplines possible to teach at the same time?
4. What may be the effects of teaching one of the arts in A, apart from the integrative disciplines in A_{12}?
5. How can technical subjects be presented so that skills are not the only things learned?
6. Should we organize our program around activities or subjects to be mastered?
7. Does content in one discipline depend on prior learning of content in another?

The answers to these and other similar questions will not be easy to decide but background knowledge of zetetics may provide ways of grappling with them more intelligently. Such was the case with the authors of the curriculum proposal described by Broudy in the Foreword to this book.

--Edmund C. Short

The Pennsylvania State University

PREFACE TO THE 1988 EDITION

The typewritten version of the Outline of Zetetics: A Study of Research and Artistic Activity, initially distributed by the Electrical Engineering Department of the University of Illinois in 1966 is no longer available. One of Prof. Tykociner's requests to executors of his estate was to have his work published in a book form to further advance and promote the purpose of Zetetics. This was accomplished in 1971 when the Outline of Zetetics was reprinted and published by Dorrance & Company. Dorrance, a vanity press, made little effort to promote this book. The book has been out of print for some time. I was therefore pleasantly surprised when I received a letter from Prof. Short, an editor of a book series for the State University of New York Press. He advised that he was considering the possibility of bringing out a new edition of the Outline of Zetetics. I am confident that this new edition will encourage other researchers to perpetuate the concept of Zetetics.

This book offers a scientific basis for coordinating and aiding the work of thousands of researchers and artists in many fields, not just those interested in curriculum. In contrast to the specialization of other sciences, Zetetics is interested in the entire range of human knowledge, classifying and systematizing knowledge, discovering gaps and expanding that knowledge which leads to discoveries, inventions and solutions to human problems.

I wish to add a few words about the author. He was my uncle and much admired. The late Dean Everitt of the Engineering College, University of Illinois, compared Tykociner to Leonardo da Vinci because he was interested in all knowledge. No area of knowledge was outside the interest of Prof. Tykociner. He was truly the universal Man, always ahead of his time, a scientist, a scholar, an inventor, a philosopher, a humanitarian, a lover of the arts and nature.

Prof. Tykociner remained continuously active to further development of Zetetics to the last days of his life. He expressed great hope for application of the principles of Zetetics to the Science of Peace (his terms was Pacifics) as a contribution to ultimate world peace.

—George Glan

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— George Glan

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PREFACE

Since the publication of my first book, Research as a Science--Zetetics, in 1959, zetetics as an area of knowledge has undergone expansions in scope and in applications. This book is a reorganization of the first and includes the many refinements of zetetics that have been developed in the past seven years.

Significant additions to this, the second comprehensive description of zetetics, are expositions of the principles of zetetics, the role of concepts in the advancement of knowledge, the environmental conditions favorable for creativity, and the organization of research centers. More comprehensive descriptions of many of the links which bind all of the arts and sciences into a dynamic zetetic system of knowledge are also new.

The book has been organized according to the subdivisions of zetetics. The first chapter is an introduction, the second is a statement of principles and definitions, and the remaining chapters discuss the eight basic sciences or subdivisions of zetetics.

In the course of developing my ideas a number of words had to be invented and others had to be given restricted meanings. For some significant terms, definitions were chosen with the sole objective of indicating the sense in which the words are used in my writings. The glossary explains briefly most of these terms.

Two pamphlets which preceded this book presented many of the ideas contained herein. Zetetics and Areas of Knowledge is based on a paper presented by myself at the Fifth Annual Phi Delta Kappa Symposium on Educational Research, held at the University of Illinois on November 4, 1963. Evolution, History, and Zetetics is based on a paper I presented before a joint meeting of the History of Science Society and the Zetetic Circle at the University of Illinois on April 28, 1962.

This book has been prepared both as a general description and exposition of zetetics and as a text for my course on "Research as a Science." I began teaching this course in September of 1962 under the auspices of the Electrical Engineering Department of the University of Illinois. The course was planned to serve as a guide for seniors and graduate students of all disciplines in beginning their careers as researchers.

I hope that this "outline" of zetetics will prove useful to my students of both the arts and sciences, to other zetetists who wish to participate in the development of zetetics, to those who seek aid in supervising laboratories and managing research centers, and to all goal seekers who desire to make a choice of their life's work.

Of the long list of friends and colleagues at the University of Illinois to whom I owe my gratitude for their interest and encouragement I wish to mention Dr. W. L. Everitt, Dean of the College of Engineering; Dr. E. C. Jordan, Head of the Department of Electrical Engineering; Mr. R. A. Kingery, Director of Engineering Publications; Mr. E. C. McClintock, Professor of General Engineering; Dr. H. von Foerster, Director of the Biological Computer Laboratory; and Dr. R. Kargon, Professor of the History of Science. My sincere thanks are due also for the valuable help rendered by Mrs. Eileen Znaniecki, Dr. T. Thacher Robinson, Mrs. Florence Pick, Mr. B. Kowaski, Mr. Peter Smith, and Mr. Hector Munoz. For the task of editing the book I wish to express my appreciation to Mrs. Eileen Znaniecki and Mr. Wayne Crouch.

The cover is a modification of a design by Larry D. Kettelkamp. The original work was the cover of my book, *Research as a Science--Zetetics*. It represents the basis of the zetetic system of knowledge and illustrates by its five concentric regions and twelve sectors (as described in Section 4.3) the trend of human knowledge as a whole to grow from the stage of darkness--ignorance--towards an all-embracing synthesis.

University of Illinois
Urbana, February, 1966

Joseph T. Tykociner

PREFACE FROM
RESEARCH AS A SCIENCE--ZETETICS

This work represents an attempt to give a brief review of ZETETICS, an area of knowledge which studies various aspects of research activity as it affects the growth of human culture. It is based on ideas I have nurtured and developed in notes since 1926. The results were occasionally reported in seminars to graduate students and in lectures.

Comprehensive reviews were given on two occasions. One was a paper "The Development of a Research Philosophy and the Science of Research," presented at the dedication of the new Electrical Engineering Building of the University of Illinois on May 21, 1949. The other occasion was a lecture on "Research as a Science" at the opening of the 1956-57 series of lectures for the History of Science Society in Urbana.

The publication of Zetetics has been delayed for years, mainly by a desire to present the material in a complete form. However, I have finally become persuaded that completeness is relative and will never be fully achieved, while the actuality of the theme makes publication urgent.

This preliminary publication, intended for only a limited circulation, consists of the first two parts of the work as planned. In Part One, the principles and aims of the science of research are treated, while Part Two contains an inventory of sciences, a catalogue of old and new sciences, with their branches, and also the arts.

University of Illinois
Urbana, October, 1959

Joseph T. Tykociner

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CHAPTER I
INTRODUCTION

1. 1. The Role of Research

Research is a cultural activity which embraces all problems related to the preservation and development of mankind. At present research activities are limited primarily to problems of defense, national health, industry, commerce, and education; all are of domestic significance. But research is becoming internationally important with its increasing effect on communication, transportation, trade, and the nature of conflicts between nations.

Research was once a hobby, an occupation of gifted individuals attracted by its aesthetic content and the joy they received from creative endeavors. When its social value became evident, it was transformed into a profession which has been steadily gaining prestige.

Research activity has now reached a stage of development unprecedented in its scope and influence on human affairs. It involves more than a thousand branches of science and engineering: it gives occupation to about one per cent of the manpower of our country and consumes a considerable part of our national budget. Today's national research budget amounts to more than the total prewar budget just a quarter of a century ago. The significance of research as a social phenomenon can be seen in the new world situations it creates, in the new industries to which it gives rise, and in the new occupations that it originates. It is one of the main cornerstones in the structure of modern society.

Research has already become an industry, centered around hundreds of research laboratories and institutes. It is now also becoming a social institution on whose proper functioning depends our very existence and survival.

Sumner H. Slichter, for instance, refers to what he calls the "industry of discovery" as being more important than any of the great inventions which led to the industrial revolution.* He regards the size of this new industry of discovery as limited at the present time by the number of available and properly trained researchers.

Another economist, Fritz Machlup, discusses in detail different aspects of the economics of research in a book entitled The Production and Distribution of Knowledge in the United States.** He has collected a great deal of statistical data about the number of scientists, engineers, and supporting personnel in industry and government agencies and shows how the funds have increased from year to year.

As a conscious factor in human evolution, research should itself become a field of investigation, a science interrelated with the arts by the creative elements of imagination and with all sciences by its capacity to unify separate fields into a synthesis of understanding which may be helpful in balancing the tendency toward increasingly narrower specialization.

While most professional activities--agricultural, medical, etc.--are built on more or less reliable foundations established by their respective basic sciences and technologies, research activity as a profession lacks the advantages which systematization and consolidation of all its aspects would offer. This situation is demonstrated in Table 1.1, which gives some examples of professions and the sciences on which they are based. The prospective zetetic vocation is included at the end of the table.

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* Economic Growth in the United States: Its History, Problems and Prospects, Louisiana State University Press, 1961, p. 102.

** Princeton University Press, Princeton, New Jersey, 1962.

TABLE 1.1
SOME PROFESSIONAL ACTIVITIES AND THEIR SCIENCES

Professions	Basic Sciences	Professional Sciences
agricultural	physics chemistry biology	agronomy science of soils animal husbandry agricultural economics farm mechanics
medical	physics chemistry botany zoology physiology psychology	diagnostics surgery preventive medicine pharmacology psychiatry
technological	mathematics physics chemistry economics	strength of materials designing electrical machinery electronics metallurgy
zetetic	zetetics	arts and sciences

Research as a profession has so far lacked a scientific foundation. This treatise outlines research in general as such a science, zetetics, and reports on the immediate tasks which have been undertaken towards its further development. It should be emphasized that zetetics is also concerned with the managerial organization necessary for activities involving research teams. Its aim is to systematize all the information we possess about research and artistic activities, including the creative processes. Its purpose is to extend that knowledge which leads to discoveries, inventions, artistic productivity, and the solution of human problems.

1.2. Research as a Subject Matter of Investigation

Scientists in search of new knowledge usually divide their problems so as to isolate a special limited field of inquiry close to their interests and appropriate to their skills. By narrowing the chosen region, the task is simplified and they can concentrate all their attention on it, thus revealing new facts valuable for further investigation.

Increasing specialization, however, conflicts with developments of the last hundred years which were so rich in achievements. These achievements have opened fresh fields of inquiry, created new sciences, and fused many sciences into unified areas of knowledge--all because of an extension of interest from specific narrow tasks to problems requiring ever-expanding perspectives.

It is necessary to lift our eyes occasionally from the particular tasks we are engaged in, to glance toward the far-reaching horizons, and to look at research as a general problem. We may then find links which connect our work with other fields of research and see how this work is interwoven with all human developments. Such an outlook leads to a realization of the need for a science of research applicable to all branches of human knowledge.

The subject matter of zetetics includes a study of the origin of systematized knowledge, of the mental processes involved in research, and of the social conditions facilitating the growth of knowledge. The interrelations between various fields of science are studied and an analysis of the methods of selection, delineation, and solution of problems is presented. Another of the main objectives is the ordering of recorded knowledge, so it can be retrieved when needed for further creative endeavors aimed at finding and filling gaps in human knowledge.

1.3. Definitions

The word "knowledge" has been used extensively in charting the field of research as a science. To avoid semantic misunderstanding, it is necessary at this stage to define briefly this and other significant words as used throughout this treatise. They will have the following restricted meanings:

Knowledge is the totality of information preserved by culture.

Science is the sum total of recorded systematized knowledge thus far accumulated by the human race.

A Discipline is a collection of parts of systematized knowledge arbitrarily selected and bound together in a manner suitable for learning, mental training, and preparation for more advanced study and research.

Research is a purposeful activity aiming at the extension of the field of knowledge and experience by

a. discovering new facts and phenomena,

b. formulating generalized relations, and

c. inventing mental and material devices for complementing human abilities.

Artistic creation is an activity which consists in applying knowledge, experience, imagination, and skill to design and produce new visual and auditory patterns of aesthetic significance.

Zetesis is the activity of both research and artistic creation. It is a word of Greek origin which means "seeking."

Zetetics is the science of research and artistic creation, concerned with collecting and systematizing data on the theory and practice of zetesis, and aiming at the expansion and unification of knowledge into a consistent system.

In connection with the definition of knowledge as the totality of "information preserved by culture," the question may arise: What is information? Here the word information refers to the component parts, the building stones, of which knowledge is composed. Thus, gathering information is the initial step in the formation of knowledge while fitting together sections of knowledge is an activity of incorporating knowledge into a science.

Another question in connection with the definition of knowledge is: How is knowledge preserved? It is preserved in our libraries, museums, and archives in the form of books, pictures, specimens, documents, and records, and also by dissemination through a system of schools and institutes of higher learning--all of them parts of culture.

1.4. The Dynamics of Knowledge

The above definitions do not stand entirely separate from one another. They form a spectrum in which knowledge spreads to wider and wider roles. The definitions gain in clarity and concreteness by associating them with the two sources of knowledge: the part accumulated by the creativity of countless past generations and the supplementary part made by contemporary contributors.

The dynamics of these two components is pictured in Figure 1.1. The upper circle represents our store of knowledge. Its inner space is divided into twelve sectors representing areas of knowledge. Our libraries and museums are the depositories where recorded knowledge is stored, cataloged, and maintained in such a way as to be accessible.

The younger generation becomes acquainted with this store of knowledge chiefly through parents and social environment (left circle) and through the schools (right circle). This knowledge develops their native abilities (middle circle) and makes them fit for a large variety of activities, represented in the lower part of the diagram by two groups of smaller circles. The activities represented by the left group of circles bring about the production of consumer and capital goods. The activities shown by the right group of circles are the services humans perform for social organizations such as schools, government, and hospitals.

In addition, there is another kind of activity for which humans develop certain skills and creative abilities, and that is zetesis, which includes research and artistic activities. The product of zetesis, symbolized by the shaded triangle Δ, is the increment of knowledge which flows into the common store. In the store of knowledge we possess a treasure which is not depleted by use, but rather increased by it. Thus, the diagram shows the process of growth and amplification of knowledge due to research and artistic activity. It is a dynamic process which feeds every

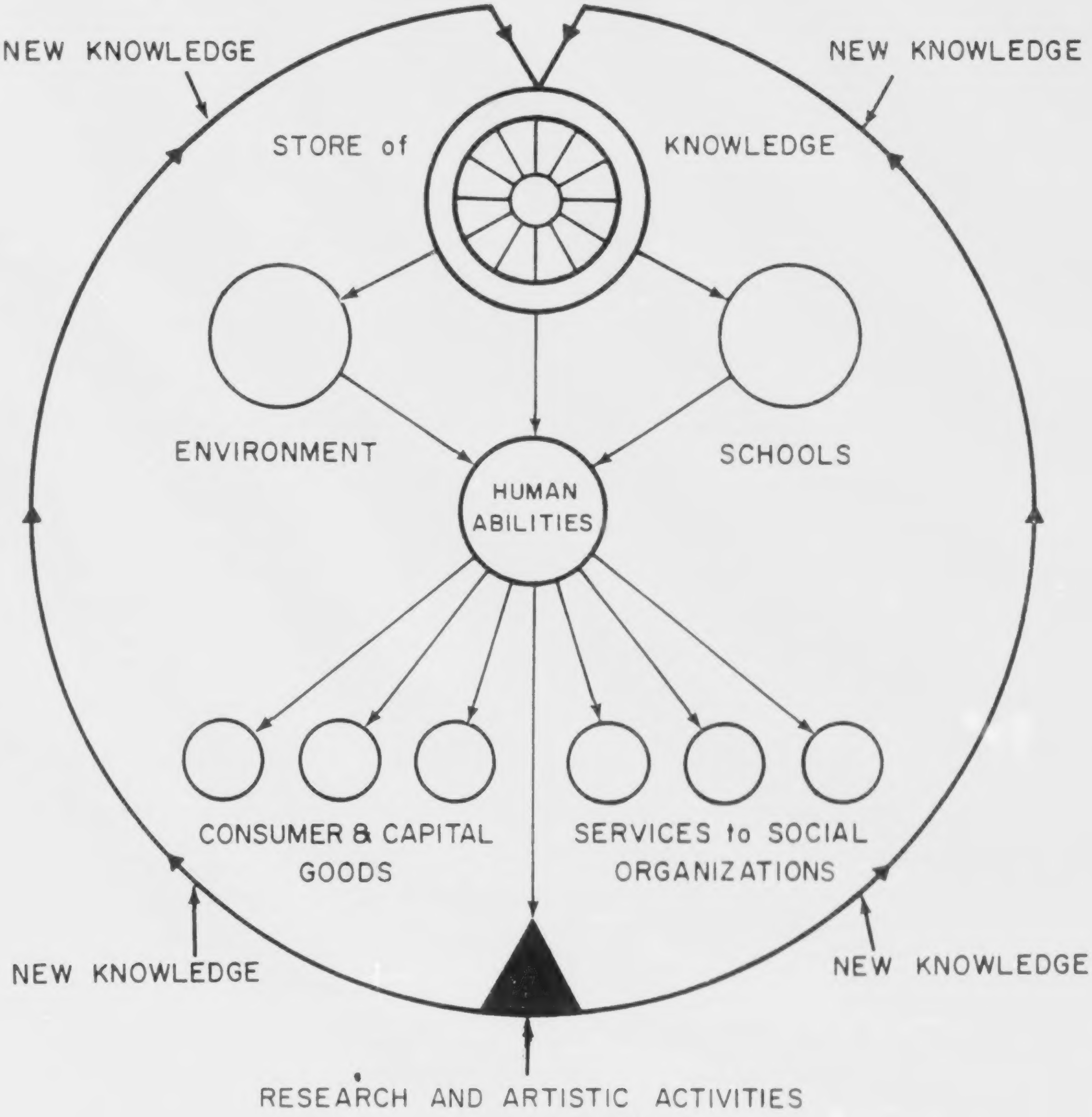
NEW KNOWLEDGE
NEW KNOWLEDGE
STORE of
KNOWLEDGE
ENVIRONMENT
SCHOOLS
HUMAN ABILITIES
CONSUMER & CAPITAL GOODS
SERVICES to SOCIAL ORGANIZATIONS
NEW KNOWLEDGE
NEW KNOWLEDGE
RESEARCH AND ARTISTIC ACTIVITIES

FIGURE 1. 1. DYNAMICS OF KNOWLEDGE

field of human endeavor with new knowledge, multiplying our resources, enriching our life materially, socially, and aesthetically, and raising our existence to higher levels.

CHAPTER II

ZETETICS: ITS PRINCIPLES AND SUBDIVISIONS

2. 1. Principles of Zetetics

Three principles form the basis of zetetics: the principle of interdependence, the principle of transformation, and the principle of controllability of the future.

a. The principle of interdependence

In the structure of the universe all parts are interdependent. Therefore, all the fractional knowledge collected, systematized, recorded, and preserved by culture must also be interdependent. A few examples taken from various realms of knowledge may serve to elucidate this principle.

The work of Galileo and Newton led to the laws of gravitation which control the motions of the earth and the bodies on its surface, as well as the motion of the solar system. So interrelated is the entire mechanical system of the universe that any change in any part affects all the other parts. Only the sensitivity of the measuring instruments may limit man's ability to determine the intensity of the effects. For instance, the tides of the oceans and the atmosphere produced by the motion of the moon cause frictions, displace the earth's center of gravity, and cause variations in the angular velocity of the earth's rotation. Any artificial satellite launched into space produces a reaction which gives rise to seismic waves, redistributes the mass of the earth, and changes the state of the entire solar system.

The slow periodic variation in the position of the earth's axis of rotation in relation to the ecliptic influences the formation of glaciers in the arctic regions and changes the climate, the flora, the fauna, and human life on the surface of the earth.

The discovery of radioactivity not only influenced the development of physics, chemistry, and astrophysics and revolutionized the economy of power production, but deeply affected the relations among nations.

The advances of the biological and medical sciences have extended the human life span and thus moved to the fore the problems of excessive population growth.

The development of the arts has been influenced by the use of the third dimension in accordance with the laws of optics and the knowledge of projective geometry. This is easily seen by comparing twelfth century paintings with those produced during the Renaissance three hundred years later. A still greater influence on the arts was exerted by the invention of photography. It diminished interest in realism and accelerated the development of impressionism, cubism, and other non-objective forms of art.

The principle of interdependence has been verified in so many fields that it may be safely applied in search of interrelations between all the arts and sciences. Thus, the absence of interrelations in certain fields signifies that there are gaps in our knowledge that must be filled by persistent research.

b. The principle of transformation

The universe presents itself as involved in a dynamic process of transformation. Everything, including human knowledge, is continuously evolving.

The concept of change has been stressed by many philosophers. Initiated by Heraclitus in the fifth century B. C., it has since then played an important role in human thinking. In modern times it has been adopted by Henri Bergson as the only enduring principle and therefore the fundamental reality.

Our experience, as well as the study of various sciences like cosmogeny, geology, anthropology, and history, supplies evidence that the universe, as we know it, is subject to continuous change. This dynamic process, usually called evolution in connection with biological phenomena, is being extended to cosmic development. However, "the process of transformation" may be a more appropriate term to characterize it.

The rates of transformation vary greatly, depending on the kinds of phenomena. Some phenomena, such as the formation of the solar system with its planets and satellites, are estimated in billions of years. Others, such as the geological stratification of the layers of the earth, proceed faster but still appear to be static, if time is measured by the scale of the human span of life.

On the other hand, many physical and chemical phenomena take place at a rate directly observable with the human senses; other observations require the use of refined auxiliary instruments. We see some changes taking place at such a fast rate that the word "explosive" is applied to them. The births of stars and nebulae (known in astronomy as nova or supernova) are examples.

A further example is the exceedingly short life of certain atoms and particles discovered by modern atom smashers and investigated by elaborate methods of measurement in atomic and nuclear physics.

Finally, viewing contemporary events, especially on the national and international scenes, we witness transformations taking place at astonishing rates. It would require a long list to enumerate just the striking scientific and technological developments which have transformed our lives and the relations between nations during the life span of a person living in the twentieth century. It is hardly an exaggeration to say that each generation lives in a world quite different from that of the preceding generation.

c. The principle of controllability of the future

Learning from experience and planning for the future makes it possible to utilize existing trends and thus partially to control their development in the interest of human survival.

Mankind's aspirations to influence the future have persisted throughout the ages and have been realized to a certain extent. Growing knowledge of the universe is bringing some success in our efforts to shape future events by creative activity.

Systematized knowledge has brought to light many generalizations derived from a study of the world around us. They show that, in spite of the apparent randomness of phenomena, the changes and the resulting transformations are not entirely chaotic and do not preclude a certain order in the universe. The predictive abilities of theories, in addition to their consistency and agreement with observation, have become the basis for evaluating their usefulness. The forecasting of weather conditions, of the exact time for sunrise and sunset, of eclipses of the sun and moon, of approaching storms, of floods, and of epidemics has demonstrated the practical value of such predictions.

Moreover, the qualities of inquisitiveness and creative imagination which *Homo sapiens* has developed in adapting to a world in continuous transition have made him capable of learning from experience and planning for the future. This has led to bold attempts to influence coming events and to consciously control evolution in the interest of human survival, social welfare, and higher aspirations.

2.2. Zetetics as an Area of Knowledge

Zetetics as an area of knowledge can be briefly summarized as follows: It is the totality of recorded, systematized knowledge related to such

methods of research and artistic production,
mental processes,
psychological factors, and
environmental conditions

as

lead to new problems,

stimulate creative imagination,
enhance selective thinking, and
generate original, fruitful ideas.

Thus, it includes as its basic factual material all the available data concerning the origin of discoveries, inventions, works of art, and great systems of philosophy. It is concerned with improving methods of inquiry (especially by expanding scientific methods), discovering gaps in knowledge, finding interrelations between the arts and sciences, and formulating new problems. Consequently, zetetics will supply the basis of education for research. Finally, it will develop a discipline for disseminating new knowledge and skills helpful in zetesis.

From the original conception of zetetics as the science of research, it has grown in many directions and developed into an area of knowledge with eight main subdivisions which can be regarded as the basic sciences of this area:

1. Zetegeny studies the emergence and growth of the arts and sciences as an evolutionary process.
2. Taxilogy is concerned with the development of the zetetic system of all knowledge, with maintaining an inventory of arts and sciences, and with methods of discovering gaps in the system of knowledge.
3. Problematology treats the selection and formulation of problems to facilitate their solution.
4. The Study of Zetesis concentrates on the development of abilities required for research and artistic activities and especially on the psycology of creativity.
5. General Methodology studies the methods of research common to all the arts and sciences and attempts to provide a general terminology usable in research and artistic activity in all fields.
6. Education for Zetesis gives guidance in research and artistic activity.
7. The Study of Environmental Conditions and Incentives which Stimulate Zetesis is concerned with creating a physical, psychological, and social climate favorable for effective research and artistic activity.

8. The Study of Research Centers treats the design of modern, large scale laboratories; their equipment and safety precautions; and the selection, organization, and management of research teams.

2.3 Zetetics as a Factor in the Growth of Knowledge

In current usage, science sometimes means our accumulated knowledge, and at other times it means our striving for new knowledge. Often it is used in both senses at the same time. To prevent such confusion in this treatise, "science" by definition is restricted to mean the store of recorded, systematized knowledge.

To express the striving for new knowledge, the word "research" is used. A diagram (Figure 2.1) may be helpful to elucidate this distinction and show the essential factors in the growth of knowledge from an unsystematized stage to the stage of integration. It consists of six rows of abbreviated information designed to represent steps in the transistion from unsystematized knowledge to integrated knowledge.

In the first row, the symbol K_u represents unsystematized knowledge, which consists of disconnected bits of information.

In the second row, the sum total of recorded, systematized knowledge is represented by the symbol K_s.

$$K_s = \sum_{t_0}^{t_1}\text{cience} \quad {}^{*}$$

Here K_s stands for systematized knowledge; t_o indicates some initial moment in the development of human culture; and t_1 relates to some later date, say 1950, the middle of the twentieth century. The Greek letter "sigma," meaning sum, is used instead of the "S" in science.

The sum contains all the systematized knowledge humanity has acquired through the ages of development in the various arts and sciences,

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*This formula and the others shown in Figure 2.1 are not meant to imply mathematical operations. They are merely symbolic representations of growth and integration.

1. K_u = Knowledge, unsystematized   Disconnected bits of information

2. $K_s = \sum_{t_0}^{t_1}$cience = Recorded, systematized knowledge $\left\{\begin{array}{l}\text{Arts } (k_1),\ \text{Math.} (k_2),\ \text{Physics } (k_3),\\ \text{Biology } (k_4),\ \text{Psychology } (k_5),\ \text{etc.}\end{array}\right.$

$$K_s = \sum_{t_0}^{t_1}(k_1, k_2, k_3, k_4, k_5, \ldots)$$

3. = Research and art. activity = Exploring, Speculating, Innovating, Inventing, Discovering.

Expansion of arts and sciences: $\underbrace{\Delta k_1+\Delta k_2+\Delta k_3+\ldots}$

New arts and sciences $\underbrace{}$ Δk_n

Ways of zetesis: Methods Creative insight Mental & exp. tools $\underbrace{}$ Δk_z

4. ΔK_s = Growth of knowledge during interval $t_2 - t_1$.

$$\Delta K_s = \sum_{t_1}^{t_2}(\overbrace{\Delta k_1+\Delta k_2+\Delta k_3}+\ldots\Delta k_n+\Delta k_z)$$

5. G = Total gain during $t_2 - t_1$.   G = ΔK_s + steps toward unification + widening perspective

6. $K_i = \int_{t_1}^{t_2}$cience, integrated → $\left\{\begin{array}{l}\text{Leading to a consistent knowledge of ways of life appropriate}\\ \text{to develop and sustain a creative human society.}\end{array}\right\}$ → An all-encompassing synthesis

FIGURE 2. 1. THE GROWTH OF KNOWLEDGE

e.g., mathematics, physics, biology, psychology, logic, anthropology, sociology, and other fields, including linguistics, history, etc. The arts and sciences shown in the figure are designated by the symbols k_1, k_2, k_3, k_4, k_5, etc. Thus, their sum gives the formula

$$K_s = \sum_{t_0}^{t_1}(k_1, k_2, k_3, k_4, k_5 \ . \ . \ . \ ).$$

It is zetesis (research and artistic activity) that makes this extensive body of knowledge continue to grow. In the course of the evolutionary process the human species is developing skills, abilities, and means for defending itself against various dangers: annihilation, physical degeneration, and boredom. These skills and abilities express themselves in activities of searching, inquiring, exploring, speculating, inventing, and investigating, which taken in their entirety are integrated by the function of research.

Accordingly, the third row in the diagram starts with a spiral, the symbol of zetesis, followed by a brief description. Like every conscious activity, zetesis is always purposeful. By our definition, its aim is the extension of knowledge and experience. Typical of zetesis are the operations, methods, and means which form links binding this activity with its aim:

a. the discovery of new facts and phenomena,
b. the formulation of generalized relations, and
c. the invention of mental and material devices for complementing human abilities.

The first two links need no clarification, but the third requires close attention. When we analyze research activity introspectively, we find that it is prevalently a struggle with our mental and physical limitations in comprehending or controlling nature and human society. As human beings we cannot see or hear clearly enough; we are unable to perceive the full range of vibrations and waves; we cannot remember all we observe or read; we cannot arrange and digest logically or apply effectively the new material we collect. We feel conscious of our inabilities all along the line of attacking problems. Acquiring skills and refining our senses still do not permit us to meet the situation adequately.

The only way human resourcefulness overcomes such limitations is by inventing instruments for detecting, recording, and measuring; by discovering mathematical methods, tables, formulas, and computing devices; and by constructing new systems of concepts, theories, and other physical and mental tools. All such means serve to complement our abilities and to extend their range.

Similarly, artistic creation has been greatly facilitated by the development of such useful instruments, techniques, and procedures as the kaleidoscope, the pantograph, projective geometry, photography, sound recording, an increasing variety of musical instruments, and many tools for drawing, painting, and sculpturing.

The result of these diverse aspects of zetesis, operating during a certain interval of time, is an expansion of the various arts and sciences by increments: $\Delta k_1 + \Delta k_2 + \Delta k_3 + \ldots$.

However, this is not all that has been achieved. If the increments are taken over a long interval of time, we find that zetesis has not only increased the store of knowledge in the known arts and sciences, but created entirely new ones, especially among those which lie in the border zones of two, three, or more sciences. We shall, therefore, add another increment to the above group, namely Δk_n, symbolizing extension by the formation of new sciences or new branches.

Is this all zetesis has accomplished? Has knowledge in the basic elements of research (as enumerated at the end of Row 3 in Figure 2.1-- namely, methods, creative insight, and mental and experimental tools) remained unchanged? By no means. Something very essential from the point of view of zetetics has been added. Actually these elements also expand and supply important contributing factors in research, and as such deserve closer attention. An examination of these factors leads to the conclusion that they may indeed represent subject matter which in its entirety constitutes a new science. Bits of information are being gathered in this new science, and a considerable increment is being made.

Thus, the above group of increments has to be complemented by still another summand, namely Δk_z. This symbol signifies an increment in the zetetic area of knowledge. So we obtain an enlarged group of increments, namely

$$\Delta k_1 + \Delta k_2 + \Delta k_3 + \ldots + \Delta k_n + \Delta k_z .$$

Accordingly, the growth of recorded systematized knowledge ΔK_s, considered for an interval $t_2 - t_1$, is represented in the fourth row of Figure 2.1 by the equation

$$\Delta K_s = \sum_{t_1}^{t_2} (\Delta k_1 + \Delta k_2 + \Delta k_3 \ldots + \Delta k_n + \Delta k_z).$$

But the total growth of knowledge cannot be represented merely by summing up all the particular Δk's achieved by research in the sciences, including zetetics. Something else must be considered, namely, growth by unification of sciences. Such a unification occurs whenever a new development unites two separate sciences, e.g., physics and chemistry into physical chemistry, or physiology and psychology into physiological psychology.

Still another factor must be taken into account--the effect of expansion of knowledge on human affairs. For instance, when the Copernican system of planetary motions became a part of our knowledge, the philosophy and meaning of human life began to change. Having lost the imaginary privileged position of being located in the center of the world, we had to replace the notion that everything moved around us and for our exclusive benefit. We know what happened three centuries later when the theory of evolution began to influence our concepts concerning the origin and development of life on our planet. And we know the changes produced in our living conditions by the applications of systematized knowledge. At the present time increased knowledge of the relation between matter and energy and of the nuclear structure of atoms forces us to revise entirely our position as a nation among the nations of the world. This means that growth of knowledge leads to an expansion of our views and brings to the foreground problems of world-wide significance.

Thus, the total gain obtained from increments in all the arts and sciences is indicated in the fifth row of Figure 2.1 by the symbol G, which represents the sum of ΔK_s, plus steps toward unification, plus widening perspective. This leads to another step in the growth of knowledge--its gradual integration, a process which may be regarded as the most important objective of zetesis. As seen from the sixth row of the figure, this integration is represented by the symbol

$$K_i = \int_{t_1}^{t_2} \text{cience}$$

in which an elongated S represents both the s in science and the symbol of integration. It means:

> Integration of science, leading to a consistent
> knowledge of ways of life appropriate to develop
> and sustain a creative human society.

Our main task at present is to find an answer to the question: Where should research efforts be directed in order to avoid man-made catastrophies? This is an example of the problems of paramount importance which cannot be solved by any special field of science, but may be solved by integrating all fields.

The time is ripe, therefore, for devoting more time and talent to the search for a synthesis of all fields of arts and sciences and to a systematic search for gaps in knowledge. This is especially true for those gaps which, once filled, will help to avoid the use of planned mass destruction.

More will be said about synthesis in a later chapter, where the various areas of knowledge and their relation to zetetics will be discussed. There the area of integrative sciences tending toward a synthesis is described. It is indicated here by the final item in Figure 2.1 which shows that each increment in the growth of knowledge reaches its culminating point only if it becomes an integral part of an all-encompassing synthesis.

2.4. Specialization and the Wider Goals of Zetetics

Specialization in research is necessary. It is the prevailing tendency due to the multiplicity and complexity of phenomena encountered in every field and also to the great variety of techniques needed in research. However, as inevitable and useful as specialization in research has proven to be, it has the following disadvantages and even dangers which should be avoided:

a. It limits the personal development of the researcher by confining his horizons to details and makes it difficult for him to get out of a one-track way of thinking. Thus, his outlook becomes narrower and narrower.

b. It deprives him of the kind of beauty, enlightenment, and inspiration which only wide perspectives can give.

c. It reduces his chances of making discoveries which lie hidden on the outskirts of a particular branch of science, often within the area of two overlapping sciences.

d. It prevents him from understanding the work of his colleagues who are active in other fields of arts and sciences, and thus makes him unprepared for teamwork in the solution of problems which encompass wider fields of research beyond the reach of his special field.

Zetetics attempts to sustain a balance between the analytical and the synthetic approach, and thus to increase the efficiency of the particular mental activity needed in research and artistic creativity.

In order to achieve such a balance, at least 10 per cent of scientists, engineers, scholars, and artists should take up a study of the synthesis of human knowledge as their life's work. The term "zetetists" seems appropriate to designate such devotees of the new profession.

As mentioned in a previous section, the adaptation of a diverse society to new conditions changing at an increasing rate poses problems which cannot be properly studied within the compass of any particular science. In order to recognize the difficulties of such problems and chart the course toward their solution, we need first of all the means for an early orientation among the prevailing trends, so as to foresee coming dangers and counteract them.

Secondly, we need a rational way of selecting far-reaching research projects and establishing the order of their importance. Thirdly, we need more systematized knowledge concerning the ways of research and of creative activities in general, so as to make them more productive and effective.

Finally, we must educate a new kind of imaginative explorer capable of building structures of knowledge out of the materials supplied by various specialized researchers. The rapidly developing new world could use a great many such "architects of knowledge--zetetists." They will have to learn how to combine knowledge derived from large groups of arts and sciences and mold it into unified structures functionally suitable, aesthetically valuable, and ethically appropriate for a higher level of living.

CHAPTER III
ZETEGENY

3. 1. Introduction

Zetegeny is the first main subdivision of zetetics. It can be regarded as a basic science in a large area of knowledge, zetetics. Its name is derived from the Greek verb zeteo (to investigate) and the suffix geny, meaning origin. As a science, zetegeny is concerned with how the potentialities of man led to the emergence of arts and sciences. Its subject matter consists of all the stages in the growth of knowledge and in the evolution of the arts and the sciences.

The biologist's name for the human species is Homo sapiens. This term designates man as the thinking, knowing creature. The chief quality which distinguishes him from all other creatures is his ability to learn by experience, to store in his memory the knowledge thus acquired, to make use of it, and to transmit it to his posterity.

Alfred Korzybski, founder of the Institute of General Semantics, defines Homo sapiens by saying:

> The human class of life differs from animals in the fact that, in the rough, each generation of humans, at least potentially, can start where the former generation left off.[*]

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[*] Science and [illegible] ~~Society~~, 3rd. edition, The International Non-Aristot~~i~~elian Library Publishing Company, Garden City, New York, 1950, p. 39.

The objective of zetegeny is to systematize and enlarge our knowledge of the development of this potentiality, which is a part of the general development of mankind. This development includes the following aspects:

1. Biological development results from the instinctive drive for self-preservation by adaptation to new conditions.
2. Social growth extends individual efforts of self-preservation by means of cooperation of individuals in groups (families, tribes, ethnic communities, nations, and international unions).
3. Cultural and creative endeavors free mankind from archaic customs and concepts, replacing them with new ones. Such endeavors foster the development of innovations--technological, artistic, and scientific--and introduce improvements in national and international organizations.
4. Finally, a trend toward conscious participation in the process of evolution utilizes the experience of the past and man's developing foresight as instruments in shaping the future.

We can summarize human potentialities by saying that biologically humans belong to the general class of mammals. They have, however, additional potential qualities which make them transcend their biological level and form cultures. In addition, having reached a certain cultural level, humans go beyond it, aspiring to still higher goals. This inherent driving power is supported by their predilection for dreaming, initiating, and developing (individually as well as collectively) new materials, devices, ideas, institutions, and ways of living. By such activities humans acquire new knowledge which generates still more innovations.

3.2. The Growth of Knowledge and the Emergence of Art and Science

In tracing the development of knowledge, we must supplement our simple definition of knowledge as "the totality of information preserved by culture." The word "information" in the sense it is used in this treatise signifies elements or bits of knowledge acquired by learning or experience. It is the raw material which becomes science by systematization.

In the last part of our definition, "preserved by culture," "culture" means works of art, the diverse works of literature, scientific achievements, technological innovations, social institutions, political and economic structures, and ideological systems which form the basis of mankind's way of life. The level of a culture depends greatly on the eagerness with which means are developed and institutions provided for collecting and preserving, for the benefit of posterity, specimens of fossils, artifacts, documents, books, objects of art, photographs, sound recordings, documentary films, and recently, video tapes. All such collections, taken together, represent the "totality of information preserved by culture." Thus, libraries, museums, and archives have become the depositories for mankind's most valuable treasure--the records of available knowledge.

Knowledge grows not only by increasing the amount of information, but also by acquiring qualities which give it value. The first valuable quality is a certain degree of reliability, depending on whether the elements of information are based on hearsay, single observations, repeated experimentations, or verified theoretical considerations. The second valuable quality of knowledge is a degree of consistency with other elements. The third such quality is sufficient comprehensiveness to include a wide field. Finally, the fourth valuable quality is coherence, which interrelates particular elements with many others.

The relation between knowledge and the emergence of art and science is diagrammatically pictured in Figure 3. 1.

In this coordinate system, time on a logarithmic scale is represented by the abscissa, while the ordinate represents the extent and quality of knowledge as determined by the degree of its reliability, consistency, comprehensiveness, and coherence. The curve shows the value of this combination increasing asymptotically toward an ideal--the unattainable truth. The shaded areas suggest that human knowledge is divided into periods of development T_1, T_2, T_3, etc., each characterized by a predominating innovation which influenced the quality of knowledge.

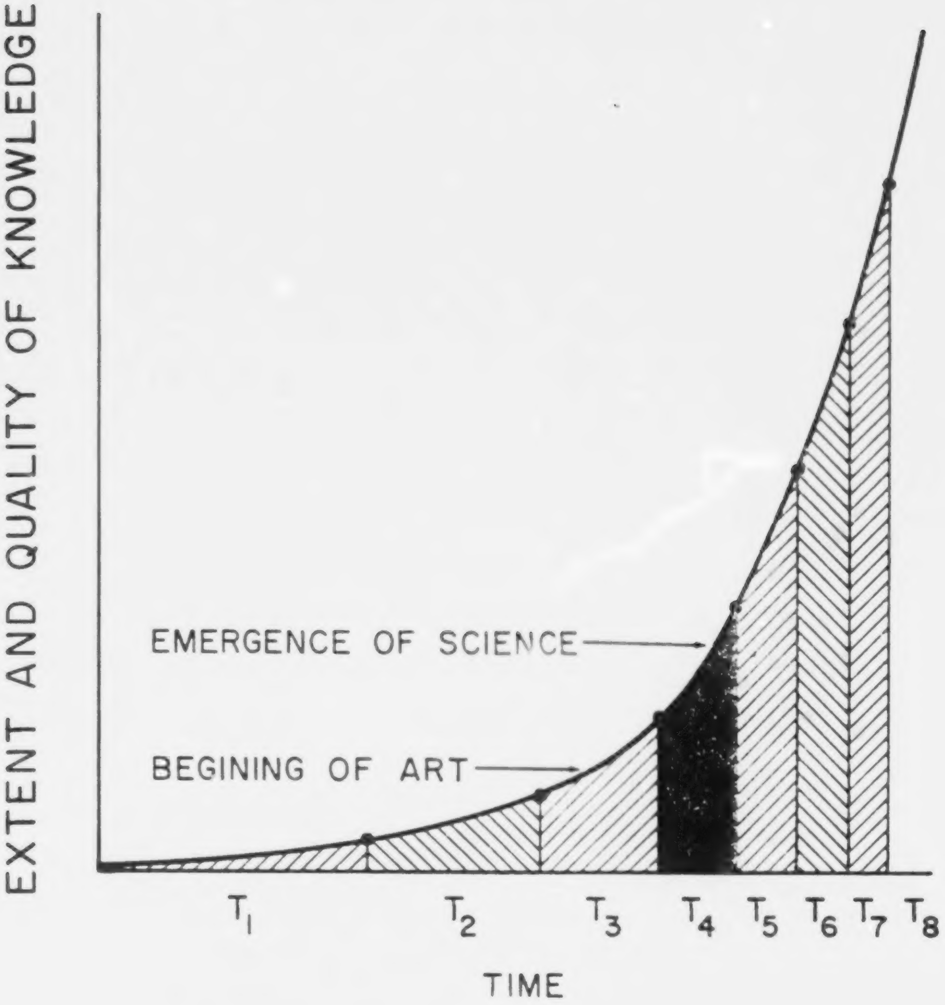

FIGURE 3. 1. STAGES IN THE DEVELOPMENT OF KNOWLEDGE

We can assume that for a very long period, T_1, after the appearance of man on earth, knowledge was instinctive, consisting in an awareness of various kinds of dangers and pleasures. Men, like other creatures, reacted by reflexes and learned gradually, as a result of their individual experiences which were imprinted on their memory. The possibility of transmitting such knowledge to other individuals or to posterity was lacking.

Only with the advent of speech during period T_2 could rudiments of knowledge be imparted by one individual to another and by one generation to the next.

In the third period, T_3, transmission of knowledge was furthered by attempts at carving and pictorial presentation. The primitive drawings of animals cut on the stone walls of caves, as found, e.g., in southern France, may have been the beginnings of art.

In period T_4, the advantage of written language was added as a powerful means of transmission of information. Knowledge then was socialized. Since memory alone was not sufficient to cope with the growing accumulation of knowledge, systematization and generalization were required. Permanent written records became possible. All this led to the emergence of science, marked in Figure 3.1 by the dark shaded area.

Further progress was achieved by the invention of printing, which is the characteristic of T_5, leading to a wide dissemination of knowledge.

The compilation of reference aids, like dictionaries, catalogs, encyclopedias, and bibliographies has further contributed to the systematization of knowledge. During this period, T_6, new sciences budded from the main stems.

Then, a new triumph in the rapid transmission of knowledge was made during period T_7 by the invention of means for recording, broadcasting, and reproducing speech, especially in connection with motion pictures and television.

We are now witnessing the next major step in the development, as foreshadowed in the progress of electronic computers and their many applications in our time. Science information retrieval techniques are being prepared to supply automatically produced bibliographies, abstracts, and reviews of any desired section of knowledge. We enter this period, T_8, hopefully expecting further expansion from a systematic investigation of factors which stimulate creativity and facilitate research activity.

Since the growth of knowledge is influenced by factors which increase with time according to the terms of a geometrical progression, the graph was chosen to represent approximately an exponential function of T. For instance, the increments of knowledge contributed by each generation of explorers; the growing number of researchers, laboratories, and research centers; the continuous improvements in measuring instruments; and the gigantic modern equipment such as atom smashers, computers, and data processing devices all accelerate the growth of knowledge. It is not yet possible to evaluate quantitatively such influences. However, it must be kept in mind that this accelerated growth does not take place evenly over all domains of knowledge, but is rather concentrated in a few areas, predominantly in the physical and biological areas. Since many fields are being neglected, especially in the zetetic and integrative areas, a solution of the most pressing problems that mankind as a whole has to face is being delayed.

3. 3. The Origin of Art and Industry

Anthropologists and ethnologists have collected evidence which shows a close relationship between artistic, industrial, and scientific developments. In the prehistoric period, when Homo sapiens lived in difficult primitive conditions, the struggle for existence required most of his time and energy. The satisfaction of hunger and the effort to survive motivated and directed almost all of his activities.

He needed tools for hunting, fishing, preparation of food, and the treating of hides for clothing and shelter. In order to improve his tools, he had to make good use of his observations and experiences, gaining a knowledge of the behavior of animals and the properties of materials.

Soon he found interest and pleasure in applying symmetry in the forming of his tools and in sculpturing them in the form of human figures, especially female ones. Then he started to draw with charcoal and to make engravings with sharpened flints on cave walls, picturing the animals and birds which he encountered while hunting. He thus developed the habit of close observation and the skill to picture the shapes and the movements important in his struggle for existence and so fundamental for artistic work.

A comprehensive description of the step-by-step development of the arts is still lacking. But studies of the Indians of the American continent indicate that artistic designs were evolved in the course of weaving grass and palm leaves into mats. The next step consisted in transferring similar designs to textile-weaving and basketry. Another step led to geometric designs in pottery making.

Thus, the arts and industry have their roots in the necessity for inventing and producing tools, and in the satisfaction derived from such elementary aesthetic values as symmetry, combined with efficiency and perfection in tool making.

In its primitive stages of development, the role of art was to serve as a means of communication, expressing emotions such as anxiety, joy, or solidarity in communal life. Strong stimuli were required, for instance, to incite a tribe to mass action. The arts of drumming and dancing were probably the first attempts to evoke the mood appropriate to particular occasions, like worship or warfare.

We may ask: What are the prospects for growth of the arts? We would have to answer that they are promising. Largely as a result of sound recording and radio broadcasting, we witness a tendency toward greater appreciation of music. Interest in painting, sculpture, and the graphic arts is being increasingly stimulated by our art schools and museums. Technological developments make it possible to extend leisure time and provide the materials, tools, workshops, and other means for enhancing artistic activities. All these factors are bound to produce favorable conditions which will encourage aesthetically inclined individuals--

the prospective artists.

3.4. Evolution of a Science

The existence of any science is a striking phenomenon. We may look at this from an evolutionary point of view, and we notice what rapid changes this science has undergone during our own generation. Scanning the records, we find that there was a time when it did not exist. How, then, did it originate? What are the conditions for its growth, multiplication, and transformation?

The studies so far conducted in zetegeny lead to the conclusion that sciences go through stages which resemble the stages of organic development. Whether this resemblance is just an analogy, a parallelism with biological development, or whether there is a hidden and deeper significance must be left for further investigation.

The adjoining self-explanatory table (3.1) represents a tentative review of the stages through which a basic science usually passes in the course of its development. For border and interconnected sciences, which originate by merging parts of two or more sciences, this table only partially applies.

The history of science furnishes much material which can be used to demonstrate this evolution of sciences. Striking instances are the gradual transformations of astrology into astronomy, of alchemy into chemistry, and of classical physics into the new physics based on relativity and quantum mechanics.

The transition which took place in the development of the life sciences is a typical example. Anthropomorphic concepts had to be discarded because they conflicted with the facts discovered by observation of plants and animals and supported by experiments in physiology and morphology. Systematization of the knowledge thus accumulated opened up new fields of investigation with special branches, i.e., embryology, ecology, genetics, bacteriology, and virology. Then the evolutionary concepts united all these fields into a wide area of biological sciences.

TABLE 3.1
EVOLUTION OF A SCIENCE

Stages of development	Sequence of characteristic events
1. Embryonic	a. Isolated, disconnected observations b. Repeated observations, tending toward distinction of differences and similarities c. Attempts to sort observations; beginning of systematization
2. Birth	d. Defined subject matter, selected and collected from a diffused store of knowledge and experience
3. Childhood	e. Subdivision of subject matter into still more specialized departments
4. Adolescence	f. Phenomenological exploration g. Empirical and mental experimentation h. Creation of models and simulators
5. Maturation	i. Establishing exact magnitude and quantity relations j. Fusion of various departments into a self-contained system
6. Multiplication	k. Discovery of new fields l. Overlapping with other sciences m. Formation of intersciences
7. Transformation	n. Tendency toward merging with other areas of science o. Further unification p. Metamorphosis based on new concepts

3.5. Development of Research

Research is a creative activity of the human mind. It performs important functions and serves definite purposes motivated by deeply rooted emotions. Whenever there are motives and aims, methods are sought for achieving the desired ends. Let us, therefore, review a tentative scheme (Table 3.2) of interrelation between motives, aims, and methods usable for a large number of sciences and their applications from the point of view of zetegeny.

The scheme presented in Table 3.2 consists of three columns: the first for motives, the second for aims, and the third for methods of research, as evolved during the various stages of intellectual development. The rows, eight in number, represent significant periods, starting from the primitive and moving along a logarithmically decreasing time scale down to our own atomic age.

Each stage contributes to the next, with the result that the store of human knowledge and the means of utilizing it progressively increase. However, this does not mean that only one set of motives, aims, and methods is working during a particular period. Most of these factors are active at all times, but one predominant set determines the characteristic development of each stage.

1. The predominant motive during the long primitive stage was fear. To penetrate the mystery which conceals the origin of human suffering and to foresee the future were the main aims. Fancy was the only method available.

2. In the second stage, awe was added to the motives, and the supreme aim was to unravel the causes behind all events and to establish relations with higher powers. Anthropomorphic methods prevailed, and magic was used in an attempt to attain these purposes.

3. During the third stage, when life had become somewhat safer, the contemplative elements found their place among the motives. There was time and occasion for wondering and thinking. To fathom the essence of things and to find the roles which control the operations of the mind

TABLE 3.2
DEVELOPMENT OF RESEARCH

Motives	Aims	Methods
1. Fear	To penetrate the mystery which conceals the origin of human suffering and to foresee the future	Fancy
2. Awe	To unravel the causes behind all events and to establish relations with higher powers	Anthropomorphic and Magic
3. Contemplation	To fathom the essence of things and to find the rules which operate the mind	Abstract thinking. Deductive
4. Inquisitiveness and desire to remember	To collect as many facts as possible and to record them exactly	Descriptive
5. Economy of mental effort	To discover relations between phenomena (laws of nature) and to predict special occurrences	Inductive and Experimental
6. Urge for all-embracing synthesis	To control conditions under which various forms of matter and energy are transformed and life develops and organizes	Unification of related fields of science
7. Desire to extend the range of human senses, memory, power, and life itself	To invent useful devices for: a) Furthering science b) Economic control c) Social organization d) Raising cultural level e) Security and defense	Close interaction of basic and applied sciences
8. Fear and anxiety for the future	To eliminate the causes of war and to unify humanity	Accelerated research. Zetetics

became a worthy pursuit. This was attempted by traditional logic involving abstract deductive thinking.

4. During the fourth stage, inquisitiveness produced gratifying results. It helped to widen the mental outlook and evoke the desire to remember the experiences gathered by observation. To collect as many facts as possible and to record them exactly became the important aims. Descriptive methods served well for these purposes.

5. Soon, during the fifth stage, too many things had to be remembered, and it became increasingly difficult to grasp the meaning of the accumulated facts. Economy of mental effort became the motive driving towards discovery of relations between phenomena. Formulation of "Laws of Nature," designed to embrace all known facts and to predict new ones, was the main objective. Inductive methods, based on hypotheses verified by experiments, became powerful constructive tools.

6. Inductive methods proved to be astonishingly fruitful. They extended the boundaries of knowledge and uncovered vistas so attractive that the slumbering urge for an all-embracing synthesis asserted itself during the sixth stage. The aim was to learn how to control the conversion of various forms of matter and energy into each other and to find out more about the processes of life, how it originates, develops, and organizes. The effectiveness of inductive methods combined with deductive methods led to the overlapping of the fields of science. Once the boundaries were crossed, a method was introduced for forming combined sciences, like electro-optics, physical chemistry, astrophysics, and biochemistry. This was followed by attempts to unify science by means of far-reaching generalizations, such as those expressed in the principles of the conservation of matter and of energy.

7. The outstanding characteristic of the seventh stage is the unprecedentedly high rate at which the store of knowledge is increasing and also the diminishing interval of time required for transferring new theories and discoveries into practical inventions. The possibility of applying new knowledge to immediate needs of human existence has revived man's old

dreams of becoming independent of the limitations set by his physical and mental abilities. He is seized by desires to transcend the range of his senses, to extend his memory, to increase his power, to lengthen his life span, and to shape his future destiny.

Such are the motives of the utilitarian stage. The main aim consists of creating useful devices for research, communication, transportation, health, economic controls, social organization, security, raising the cultural level, and providing defense. All this is being attained by methods which are typical of various branches of engineering. The method consists in a functional division of activities among cooperating teams, so that close interaction of basic and applied sciences fuses a variety of abilities into one common effort. These include inventing, planning, developing, designing, and testing.

The machine age has not yet achieved its ultimate purpose of relieving humanity from drudgery, but a new age is already on the march. The great question for us, interested in the future of mankind and especially in the future of research, is what will be the main motives, aims, and methods in the coming age of nuclear power complemented by electronic computers and automation. At this stage, the curtain of uncertainty, made up of innumerable questions, blurs our foresight.

8. We are entering the eighth stage. The motive of fear, strong in the primitive stage of development, is evidently returning. Men first experienced fear of the unknown. But, having overcome many obstacles, they became acquainted with the elementary forces of nature and gradually learned to utilize them for their own purposes. Nowadays, dismayed by the growing complexity of modern living and the limitations of their own knowledge, they are returning to the stage of fear and anxiety about the future. Such situations occur whenever pressing problems cannot be or are not solved, but are postponed indefinitely. Wars, revolutions, famine, and other disasters may result from sheer ignorance or lack of foresight. Therefore, we have become deeply concerned with the growth of knowledge.

The western world lived through a similar period of fears and hopes before the dawn of the Renaissance again spurred interest in the sciences. It looks as if motives have a tendency to change periodically in their emphasis. Now again we wonder why, in spite of the many positive potentialities of science and technology, there should be so much suffering and uncertainty. Again fancy tends to replace scientific methods in attempts to solve human problems, or reliance is placed on passive acceptance of fate or predestination.

Nevertheless, by extrapolating our experience we can foresee some of the new factors which will come into play in addition to those acting at present. We can safely assume that foresight or prediction, one of the powerful tools of engineering methods, will continue to shape the future. We know that the future is endangered by the accumulation of unsolved problems, especially in the domain of international, social, and economic relations. This may lead to the disunity and the war we wish to prevent. Therefore, may not accelerated research in all domains embraced by zetetics contribute to gaining further insight? Those insights in the most vital fields of knowledge may mitigate our fears and awaken new hopes.

CHAPTER IV
TAXILOGY

4. 1. The Objectives of Taxilogy

Taxilogy is the second basic subdivision of zetetics. It is concerned with the following objectives:

a. To supply and maintain an inventory of all the arts and sciences.

b. To develop a zetetic system of knowledge to facilitate orientation in research and education.

c. To suggest to an inquiring mind new relations between the various parts of knowledge.

d. To search for new branches of the arts and sciences.

The term taxilogy was chosen as suitable to cover the above tasks. It is derived from the Greek taxis (arrangement) and logos (science).

4. 2. A Systematized Inventory of Arts and Sciences

Every science, having reached a certain early stage of its development, requires as a condition of its further growth a systematic, exhaustive list of its ever-expanding subject matters. Within each particular science such a list constitutes an inventory to be studied and ordered. To obtain patterns of order in objects, phenomena, ideas, and generalizations--the very essence of zetesis--such inventories must be established and occasionally revised and supplemented.

Sciences which have reached maturity already possess such inventories. For instance, linguists have catalogs of words called dictionaries. Classicists have catalogs of manuscripts, and historians make use of chronological lists of events. Linnaeus, Buffon, and others created a system of classification with extensive catalogs of plants and animals called taxonomy, which became the basis of systematic botany and zoology. This makes possible the assignments of names to various groups and the observation of common characteristics as a basis for classification.

Mineralogists have catalogs of crystals and minerals. Physicists have their ever-growing tables of atomic elements and nuclear particles which are playing an outstanding role in furthering discoveries. Chemists keep up-to-date lists of inorganic and organic substances. A list of diseases and their symptoms, together with the famous materia medica, forms the foundation of medicine. Astronomers have produced catalogs of planets and stars. They are now engaged in the gigantic task of completing a record of light-emitting nebulae with the aid of photographic cameras attached to telescopes designed to explore the vast regions of skies 400 million light-years in depth. Their catalogs are being supplemented by contributions in a new branch of astronomy called radio astronomy, whose aim is to detect invisible stars and nebulae by means of radiotelescopes sensitive to electromagnetic radiations of frequencies lower than the optical ones.

Even mathematicians, who are so intent on claiming that their domain of knowledge is free of everything concrete, possess (in addition to lists of formulas) collections of concrete models of two-, three-, and many-dimensional curves.

Has not the time come to systematize the sciences, their branches, and knowledge as a whole, by making an inventory of ancient and modern sciences with their definitions and interrelations, so as to foresee trends and envisage new developments? Indeed, it is one of the tasks of taxilogy as a branch of zetetics to supply such an inventory as a guide and tool for further investigations.

At present a list of over 1,400 items enumerating arts and sciences in alphabetical order is being compiled. Each item is provided with a brief description. A supplementary list consists of the same items classified into groups according to their areas of knowledge.

4.3. The Zetetic System of Knowledge

Various classifications of the arts and sciences exist at the present time, but none has been designed as a guide in finding gaps in systematized knowledge. One of the objectives of zetetics is to obtain an overall view of our continuously growing store of systematized knowledge for this purpose. As a step in this direction, it was necessary to devise a scheme containing all the arts and sciences as component, interrelated parts of a consistent system of knowledge. The scheme used here consists in the division of systematized knowledge into twelve areas, each containing a number of sciences with a definite common function.

The areas are namely:

A_1. The arts
A_2. Symbolics of information
A_3. Hylenergetics
A_4. The biological area
A_5. The psychological area
A_6. The sociological area
A_7. Exeligmology
A_8. Pronoetics
A_9. The regulative area
A_{10}. The disseminative area
A_{11}. Zetetics
A_{12}. The integrative area

The zetetic system of knowledge brings out interrelations between the various areas of knowledge and serves as a guide to the multifarious relations among the areas and the sciences. It facilitates orientation for goal-seekers, just as a map does for travelers who are lost in the maze of roads and streets which cross a large metropolis in all directions.

Every interconnected group of sciences, every subdivision of an art or a science, and every particular branch of a science, must find its place in the system.

Figure 4.1 shows how the zetetic system of knowledge was presented in my book Research as a Science--Zetetics. It was called the "ring diagram" because it consisted of twelve concentric rings, each representing an area of knowledge.

Further development of zetetics led to a more elaborate and suggestive presentation for which the name "sector diagram" seemed appropriate. Figure 4.2 shows the new arrangement, which consists of five regions (I, II, III, IV, and V) separated from each other by concentric rings, a, b, c, and d. Outside of the largest ring a extends the black Region I of the unknowables. This region is impenetrable by the human mind because of the limitations of both perceptual and conceptual abilities of Homo sapiens. In some distant future, parts of this region may become accessible, if evolutionary development favors the extension of man's nervous system. Between the large rings a and b lies the shaded Region II, the knowables which are not yet known; the white Region III, between rings b and c, contains the as yet unsystematized knowledge.

Knowledge which becomes systematized occupies Region IV between the middle rings c and d. There it is fractionalized into twelve sector-like areas (Ar to In), separated by dotted boundary lines, each containing a cluster of small circles representing related sciences which tend toward unification. A single science is pictured as a starlike circle whose circumference we can imagine as expanding with the growth of this particular science. The magnitude of the small circles indicates the relative amount of systematized information stored in each of the various sciences at any given time. The length and the number of the radial projections attached to the circles may serve to suggest the extent to which the sciences are interconnected at a given stage of development.

These projections represent symbolically the origins of lines of mutual influence, not only between sciences within a particular sector,

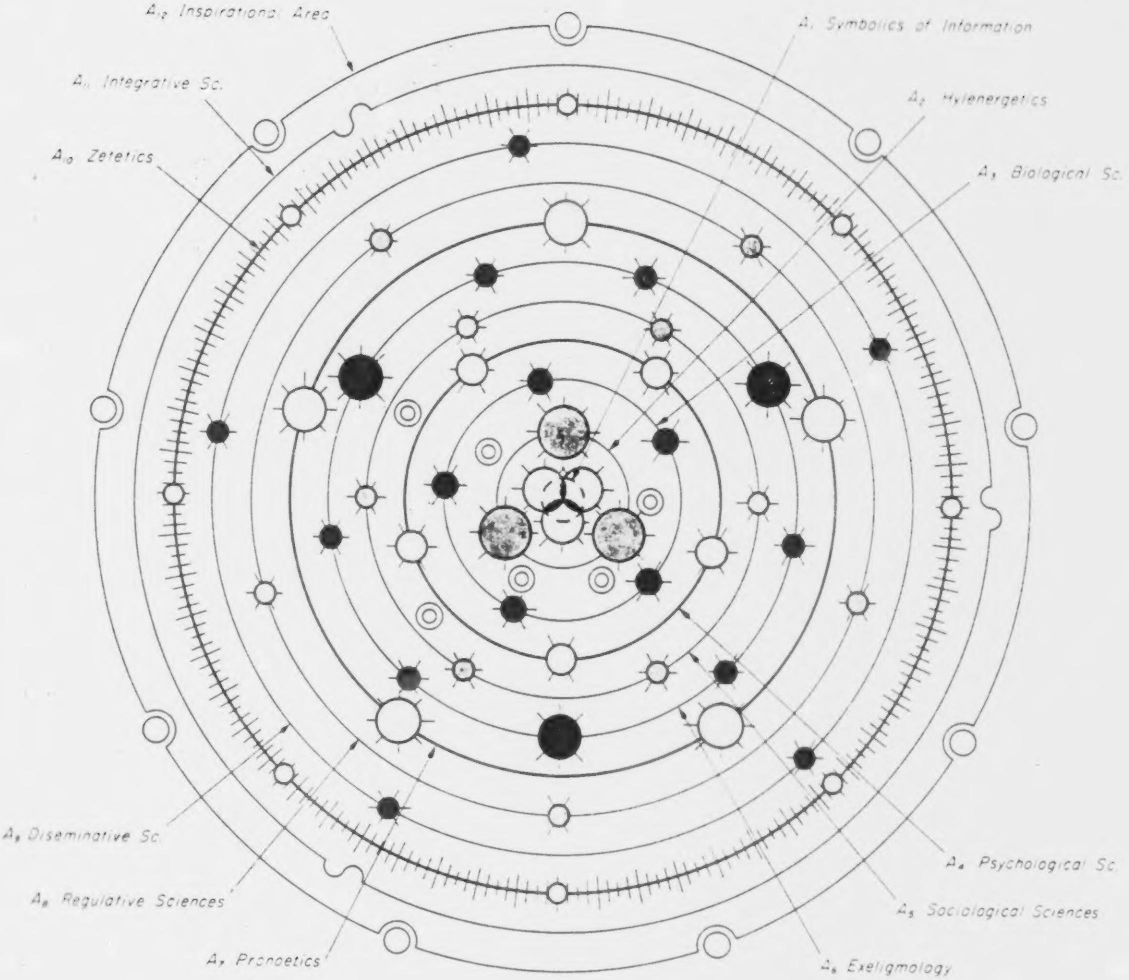
A_{12} Inspirational Area
A_1 Symbolics of Information
A_{11} Integrative Sc.
A_2 Hylenergetics
A_{10} Zetetics
A_3 Biological Sc.
A_9 Diseminative Sc.
A_4 Psychological Sc.
A_8 Regulative Sciences
A_5 Sociological Sciences
A_7 Pronoetics
A_6 Exeligmology

FIGURE 4. 1. RING DIAGRAM OF KNOWLEDGE

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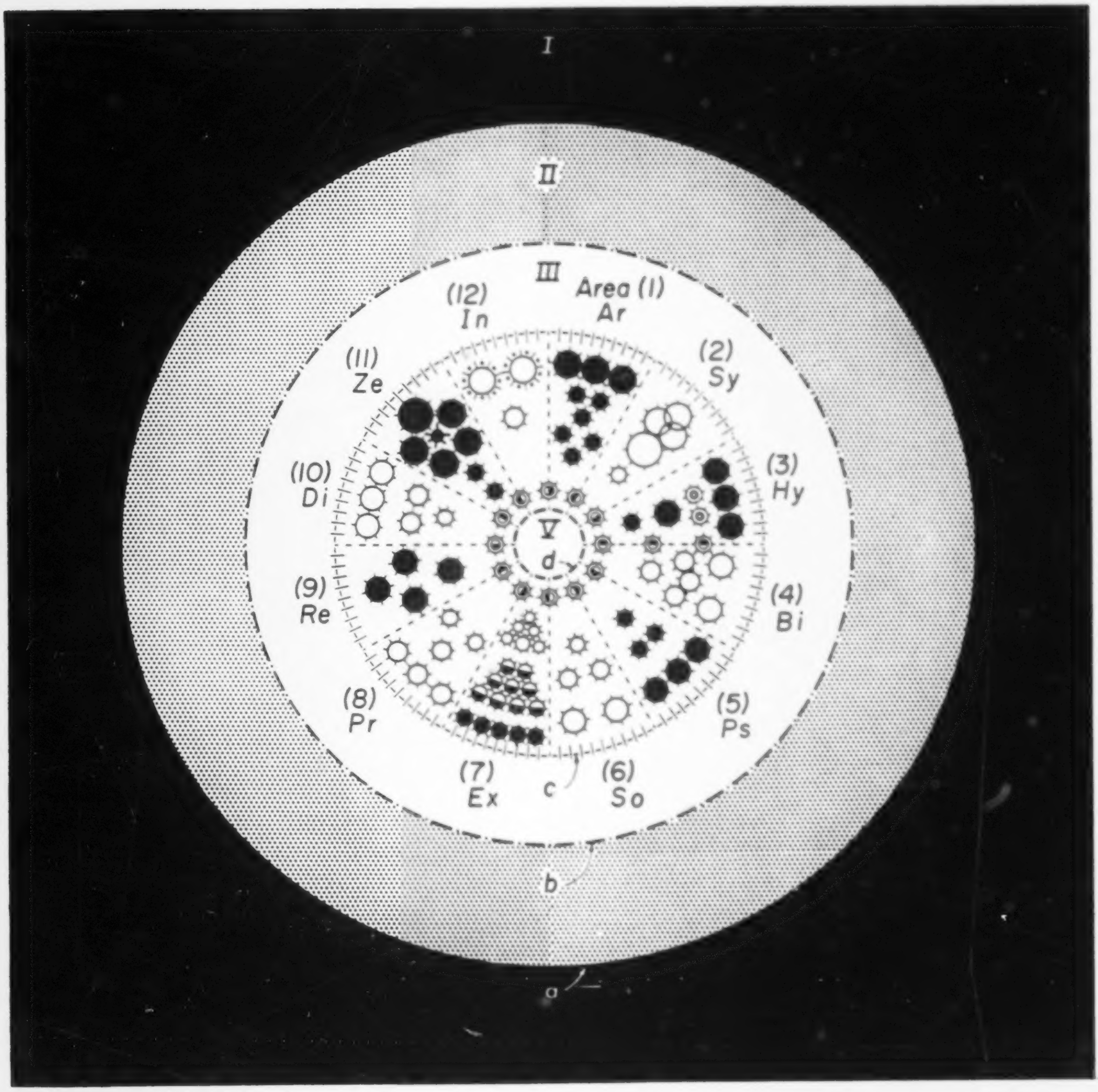
I
II
III
Area (1)
Ar
(2)
Sy
(3)
Hy
(4)
Bi
(5)
Ps
(6)
So
(7)
Ex
(8)
Pr
(9)
Re
(10)
Di
(11)
Ze
(12)
In
V
d
c
b
a

FIGURE 4. 2. SECTOR DIAGRAM OF REGIONS AND AREAS OF KNOWLEDGE

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but also between sciences of different sectors. The complete lines of influence were omitted to avoid complicating the picture. Similar projections are drawn on ring c to indicate the penetration of knowledge from the unsystematized Region III into the systematized Region IV.

The overlapping of small circles signifies a tendency toward unification of the respective sciences. A nonshaded double circle within a sector indicates an interscience within an area, while double circles drawn directly on the dotted border lines show sciences which tend to interconnect two areas. The more the areas become interrelated, the more double circles will be placed on the border lines. The more knowledge we gain concerning the interrelations of the areas with each other, the closer they come to integration. For a complete integration of human knowledge, Region V is reserved.

In this diagram one such double circle has been placed on each of the twelve border lines to indicate the particular science which at the present stage of development binds closely the adjacent areas of knowledge. For the sake of clear visualization, these sciences are collected close to ring d. However, one of the radial lines shows two more double circles, which serve to indicate that more is known about the interrelations between areas Hy and Bi than about interrelations between the other areas.

Ninety-eight circles are drawn on the sector diagram, representing either basic sciences or their branches. There are many more sciences, branches, and sub-branches which could not be pictured on the diagram for lack of space.

We may look on the three regions encompassed by ring b as an imaginative model representing the brain of mankind. Region V may thus become a coordinating center for all the recorded basic information which the human species has collected, systematized, and integrated during the historical period of its existence. Unfortunately, this region is still vacant, reserved (as already mentioned) for the complete integration, i. e., for a synthesis which would lead to a world view not only based on the totality of human knowledge, but also fusing the aspirational with the inspirational in human nature.

Figure 4. 3 indicates the significance of the described system of knowledge as part of zetetics. The central portion of the chart contains the five regions and the twelve sectors of knowledge. This core is surrounded by twelve interconnected rectangular spaces in which the particular sciences of each area are enumerated and referred by arrows to the respective sectors. The links between the areas are indicated by the names of the intermediate sciences inscribed between the adjacent rectangular spaces. The lower part of the chart contains the main definitions discussed in Chapter 1.

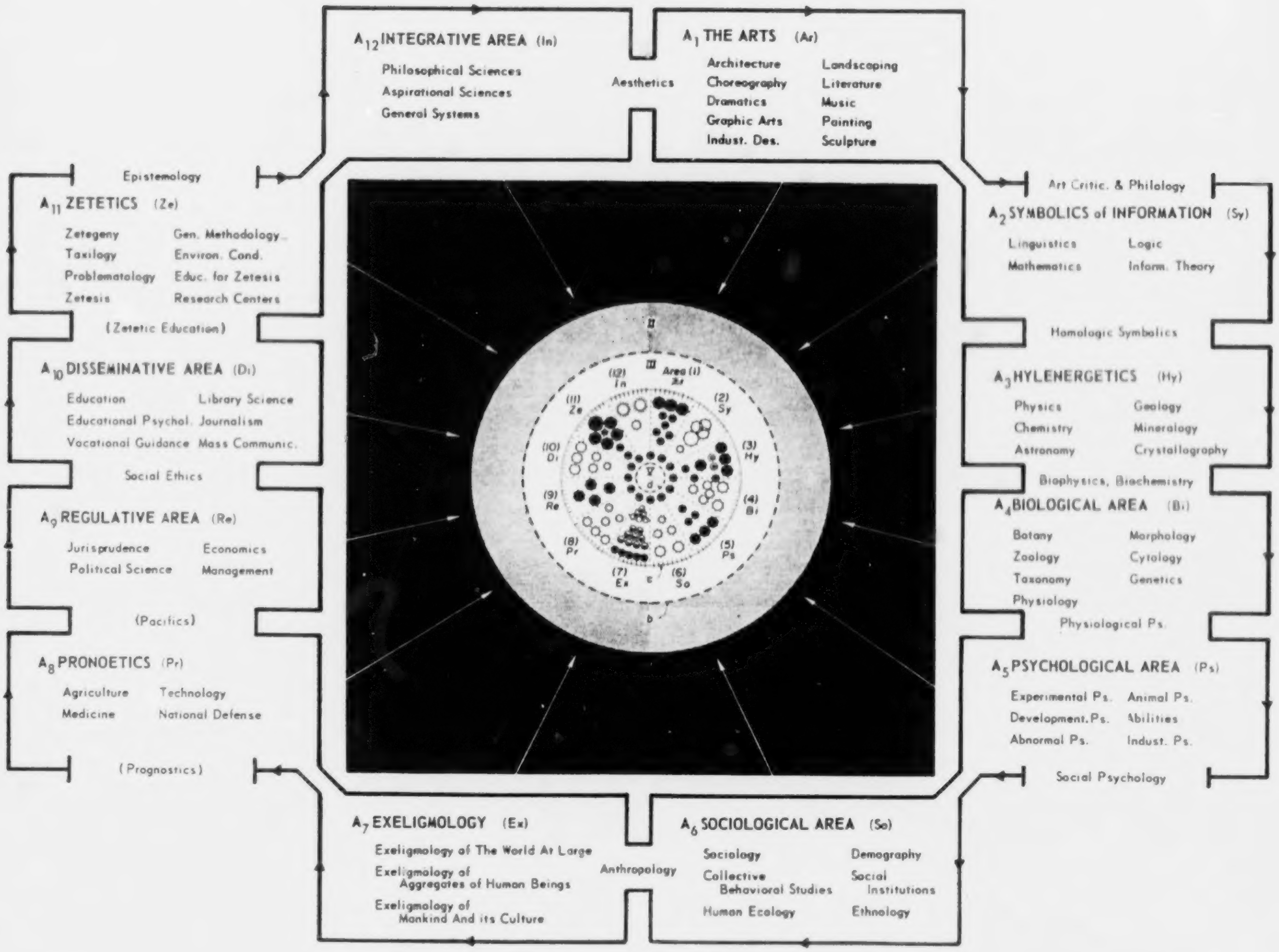
The importance of the zetetic system in connection with the creation of new knowledge by searching for gaps in the existing knowledge remains to be mentioned. As we shall see, it has already led to formulation of new sciences and promises to yield more results in the future. Its role is comparable to that of the periodic table of chemical elements, which continues to be a powerful tool of discovery in physics and chemistry. Similarly, taxilogy with its system of knowledge deals with known "elements" of knowledge and facilitates the discovery of new ones.

4. 4. The Areas of Knowledge and Their Basic Sciences

Let us review briefly the twelve areas of knowledge, as represented in Figure 4. 3 by sectors Ar to In, and indicate the principal links which bind these areas as a whole.

A_1. The Arts (Ar)

The arts occupy the first sector, Ar, of the diagram. This area is preceded by Area 12 (the integrative area) with which it is linked by the philosophical study of aesthetics. The arts are the results of creative activity (zetesis) which, evoked by inspiration, produces unique objects of aesthetic quality. In their turn, objects of art kindle the dim light of creativity, intensify its brightness, and accelerate the development of this priceless faculty, so indispensable in the process of human evolution. Besides stimulating and sustaining zetesis, they perform a prophylactic


A12 INTEGRATIVE AREA (In)
Philosophical Sciences
Aspirational Sciences
General Systems
Aesthetics
A1 THE ARTS (Ar)
Architecture
Choreography
Dramatics
Graphic Arts
Indust. Des.
Landscaping
Literature
Music
Painting
Sculpture
Art Critic. & Philology
A2 SYMBOLICS of INFORMATION (Sy)
Linguistics
Mathematics
Logic
Inform. Theory
Homologic Symbolics
A3 HYLENERGETICS (Hy)
Physics
Chemistry
Astronomy
Geology
Mineralogy
Crystallography
Biophysics, Biochemistry
A4 BIOLOGICAL AREA (Bi)
Botany
Zoology
Taxonomy
Physiology
Morphology
Cytology
Genetics
Physiological Ps.
A5 PSYCHOLOGICAL AREA (Ps)
Experimental Ps.
Development. Ps.
Abnormal Ps.
Animal Ps.
Abilities
Indust. Ps.
Social Psychology
A6 SOCIOLOGICAL AREA (So)
Sociology
Collective Behavioral Studies
Human Ecology
Demography
Social Institutions
Ethnology
Anthropology
A7 EXELIGMOLOGY (Ex)
Exeligmology of The World At Large
Exeligmology of Aggregates of Human Beings
Exeligmology of Mankind And its Culture
(Prognostics)
A8 PRONOETICS (Pr)
Agriculture
Medicine
Technology
National Defense
(Pacifics)
A9 REGULATIVE AREA (Re)
Jurisprudence
Political Science
Economics
Management
Social Ethics
A10 DISSEMINATIVE AREA (Di)
Education
Educational Psychol.
Vocational Guidance
Library Science
Journalism
Mass Communic.
(Zetetic Education)
A11 ZETETICS (Ze)
Zetegeny
Taxilogy
Problematology
Zetesis
Gen. Methodology
Environ. Cond.
Educ. for Zetesis
Research Centers
Epistemology
II
III
Area (1) Ar
(2) Sy
(3) Hy
(4) Bi
(5) Ps
(6) So
(7) Ex
(8) Pr
(9) Re
(10) Di
(11) Ze
(12) In
a
b
c
d
v

KNOWLEDGE:
Is the Totality of Information Preserved by Culture

SCIENCE
Is the Sum Total of Recorded Systematized Knowledge thus far Accumulated by the Human Race

ZETETICS
Is The Totality of Recorded Systematized Knowledge Related to

Such Methods of Research
Mental Processes
Psychological Factors and Environmental Conditions

As Lead to New Problems
Stimulate Creative Imagination
Enhance Selective Thinking and Generate Original, Fruitful Ideas

ZETESIS Is a Purposeful Activity Aiming at the Extension of the Field of Knowledge and Experience by

a. Discovering New Facts and Phenomena
b. Formulating Generalized Relations
c. Inventing Mental and Material Devices for Complementing Human Abilities
d. Designing Visual and Auditory Patterns of Aesthetic Significance

FIGURE 4. 3. ZETETICS AND THE ZETETIC SYSTEM OF KNOWLEDGE

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function in overcoming boredom, which with increasing leisure is becoming a serious social problem.

It is the use of symbolic structures based on sense perceptions and appealing to the imagination which unifies the various parts of this area. Area 1 is, indeed, characterized by the use of symbolic presentation, patterned by a sequence of sounds and intervals of silence in music, or by colors distributed in various shades in painting, or by multidimensional shapes in sculpture, or by motions of the human figure in ballet.

A further characteristic which unifies all the arts is that they serve as a means of communication. The artist's role is to transmit his impressions and ideas to the public which reacts by expressing approval or displeasure.

Thus, artists and writers are concerned with symbolic patterns of light, shade, colors, sounds, words, and sentences, all forming images which, besides evoking aesthetic emotions, enrich our experience and serve as a medium of communication.

This area includes (in alphabetical order):

- architecture
- choreography
- dramatics
- graphic arts
- industrial design
- landscaping
- literature
- music
- painting
- sculpture

Another characteristic of creative activity in arts and literature is the predominant role which the imagination and skill of individuals play in the process of creative endeavor in these fields. In all the other areas, the results of any zetetic endeavor are never final: a creative individual can contribute in his field by adding new information to the existing body of knowledge accumulated by the creative work of the countless humans who live or have lived all over the inhabited surface of the earth and who have been active during ages of cultural development.

In the arts and literature, on the contrary, each work must be unique and complete. Its originality and aesthetic value is regarded as more important than the technique and subject matter. However, the urge to create which is experienced by artists is similar to that experienced by researchers in other areas. Artists are also trying to contribute to the advancement of their respective arts by their endeavors to develop new ideas. They have established whole schools of new thought and new techniques, blazing new trails in order to succeed in expressing what has not been effectively expressed before.

As to the aesthetic element involved in art and literature, it is not entirely absent in scientific or technological creations. Mathematicians often mention the inner harmony and beauty they find in their field, and they like to speak of "elegant" solutions of their problems. Similarly, astronomers, physicists, and biologists are often impressed by the beauty, the perspectives, and the astounding horizons which their generalizations reveal.

Area 1 does not stand isolated from the other areas, but is a constituent part of a cyclic arrangement of all the areas which form a systematically interrelated whole. Art criticism and philology connect Area 1 with Area 2, the symbolics of information.

A_2. Symbolics of information (Sy)

The next sector, Sy, represents the result of a chain of developments which led from primitive attempts of communication by signs and gestures to articulated language and onward through systems of symbolic formalization to the as yet undeveloped stage of systematic concept formation.

This area also deals with symbolic structures. However, its elements are arbitrarily selected to facilitate the process of reasoning. Here the rigorous consistency of its symbolic structure is the predominant factor, while in Area 1 the originality and the aesthetic appeal are the mainsprings of creative endeavor.

The Sy sector includes:

linguistics
mathematics
logic
information theory

The tendency of the first three sciences to merge is indicated in the diagram by overlapping circles. All of these sciences supply symbols, abstract concepts, and rules of operation for the purpose of ordering and communicating information in a consistent way. Because an abundance of symbols is involved, "symbolics of information" has been chosen as a suitable name for this area of knowledge.

It appears as if the main factor which leads to the unification of these five sciences is emerging rapidly in the form of a general theory of semantic information, such as that initiated by the work of Bar-Hillel and Carnap.* In their theory the contents as well as the statistics of the symbols are considered, and the theorems they developed can be applied to fields involving semantics.

This group of sciences, thus unified, makes communication possible. It enables members of the scientific community all over the world to keep in touch and understand each other's ideas and work. It is especially useful for the readers of scientific papers, and it also facilitates an individual's "arguing with himself."

Mathematicians, logicians, and other scientists of area Sy are, like artists, concerned with patterns. However, the patterns they form have a cognitive character which, nonetheless, evoke feelings of elegance and beauty. Their images consist of theories, inferences, rules, and laws which are indispensable for the development of the sciences of other areas.

Since none of the known sciences of Area 2 is specifically adapted to be a direct link with the next area (A_3), the zetetic point of view requires searching for a new science to fill the gap. This led to the formulation of the science "homologic symbolics." More will be said about this science in the section which summarizes all the specific interconnections linking the various areas of knowledge.

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* Symposium on Theory of Communication, Willis Jackson, ed., London, 1952, pp. 503-512.

A_3. Hylenergetics (Hy)--sciences dealing with matter and energy

The area of systematized knowledge often referred to as the physical sciences is shown by the third sector Hy. Its basic sciences are:

physics
chemistry
astronomy
geology
mineralogy

Because most of the processes they exhibit lend themselves readily to mathematical treatment and to precise measurements, the first three are often called exact sciences. Figuratively, they are spoken of as fundamental blocks on which knowledge of the structure of the universe is built.

This is, indeed, an area embracing the knowledge of both the microcosmos and the macrocosmos. They study the multitudes of phenomena activated by aggregates of nuclear particles, atoms, and molecules from the tiny crystalline units to the immense units embodied in the earth, the solar system, and the galaxies. All these units act singly and in their entirety as sources of kinetic radiant energy which they interchange.

The rapid expansion of this area during the last hundred years has led to a remarkable unification of the various branches of each of its basic sciences and produced far-reaching, experimentally verified generalizations based on the equivalence of matter and energy. Such a synthesis justifies the name "hylenergetics" chosen for this area of knowledge. It is a combination of the Greek word "hyle," signifying matter, and "ergon," signifying work. It means "study of states of energy and matter convertible into each other."

In Figure 4.3 the three outer circles in sector Hy represent physics, chemistry, and astronomy. Two intersciences are represented by double circles--namely, physical chemistry in proximity to physics and astro-physics in proximity to astronomy. The other two circles represent geology and mineralogy.

One connecting link binding this area with the next is marked by a double circle drawn on the adjacent radial line. This circle represents crystallography, a branch of mineralogy, which remotely suggests the first characteristic of living organisms, growth. There are two other double circles on the same radial line. These represent biophysics and biochemistry--links binding sector Hy with Bi.

A_4. The biological area (Bi)

The many aspects of the living world, as manifested in processes of growth and reproduction, are studied by the sciences of area Bi. They are often called the "life sciences" and are unified by the principle of evolution. Their subject matter ranges from the simplest units of life as they appear in single cells to complex organisms of the plant and animal kingdoms in an immense variety of forms and functions.

So great is the variety of organisms (micro, plant, and animal) that a particular science, taxonomy, is devoted to the identification and classification of biological objects into species, genus, family, etc. The wealth of information produced by the biological sciences could hardly have been obtained without application of the results of the sciences of the preceding areas. Especially helpful were mathematics, physics, and chemistry. It is sufficient to indicate, as examples, the role of optics and electronics in supplying techniques and devices indispensable in biological explorations and also the role of geological explorations which led to paleontology--the basis of systematized knowledge of evolutionary processes.

The basic sciences are:

botany
zoology
taxonomy
morphology
cytology
genetics

They are linked with the following area (Ps) by physiology, which is closely connected with physiological psychology.

A_5. The psychological area (Ps)

For centuries psychology was considered the science of the soul (psyche). As represented by philosophical psychology, it developed into speculative investigations of the human mind. Introspection and observation led to a variety of psychological systems. The modern course of development was started with psychophysics when physical methods of measurement were applied to the study of quantitative relations between stimuli and responses.

The area of psychology became even more closely connected with the biological sciences when by the use of experimental methods a new field of research was opened, that is, experimental psychology which is closely related to physiological psychology. Thus, the latter became an interscience linking biology with general psychology. Application of the concepts of evolution then led to still another expansion of the field of study, namely, animal or comparative psychology. Experimental investigations suggested that each individual organism, acting as the result of integrated operations of its component organs, as a whole shows behavioral patterns of adjustment to its environment. Subsequently such studies were extended to small and large numbers of individuals acting as a group. This gave rise to group psychology, which together with social psychology, constitutes a binding link with the area of sociology. Therefore, social psychology is shown in Figure 4. 3 as a double circle drawn on the border line between Ps and So.

So intimately interconnected appear the biological, psychological, and social sciences that a movement to unify all three into an area of behavioral sciences is evolving as an attempt towards further consolidation of systematized knowledge.* A noteworthy advance in the same direction was initiated by the activities of the Society for General Systems Research, which since 1956 has been publishing its yearbook, General Systems. The present stage of these endeavors has not yet reached the necessary level for such a unification. However, these zetetic activities indicate an insistent search for a principle which could serve as a basis for coordinating psychological and sociological research in the manner in which relativistic field theories and quantum mechanics are attempting to transform the hylenergetic area, and likewise the theory of evolution is tending to unify the biological area of sciences.

So far this search has not yielded a principle capable of interconnecting the totality of biological, psychological, and social sciences. As closely as these three areas may appear to be related, they cannot as yet be treated as one, already unified area. Therefore, it is justifiable to regard, at the present level of development, Area 5 of the psychological sciences as occupying the intermediate sector between the biological and sociological areas.

A_6. The sociological area (So)

In the area of sociological sciences knowledge is being collected and systematized relative to the phenomena and conditions which produce, sustain, or change the many various forms of individual and group life. Sociology, originally called "social physics" and sometimes defined as "the science of society," is the basic science in this area of knowledge.

Founded by August Comte in the year 1822, sociology's young age of just over a century and a quarter is hardly sufficient to enable it to consolidate its branches into a well-defined and unified area. In its growth toward adolescence, sociology is still divided into conflicting schools of thought which differ from each other in answers to such fundamental questions as those enumerated in N. S. Timasheff's book, Sociological Theory.*

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*Toward a Unified Theory of Human Behavior, ed. Roy R. Grinker, Basic Books, Inc., 1956, p. 375.

> What is society and culture?
>
> What are the basic units by which society and culture should be analyzed?
>
> What is the relationship between society, culture, and personality?
>
> What are the factors determining the state of a society and a culture, or change in society or culture?
>
> What is sociology and what are its appropriate methods?

However, in this area, as in any other area of knowledge, the approaching state of maturity is indicated by a decline in the range of disagreement in theoretical matters.

The following main subdivisions of the social sciences, as represented in Figure 4. 3 by circles in sector So, show the inherent interrelation of their subject matter with other areas of science:

1. Sociology, the study of relations between human beings, individually and in groups.
2. Collective behavioral studies, by their relation to group and social psychology, represent the link with Area 5.
3. Human ecology binds Area 6 with the biological sciences, A_4, by its connection with animal sociology and ecology.
4. Demography, the study of the vital processes and of the distribution and composition of popu-

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* Doubleday & Co., Inc., Garden City, N. Y., 1955, p. 11.

lation aggregates, supplies the necessary data for the study of human ecology and social institutions.

5. Social institutions, their structure, statics, and dynamics, form the central part of the subject matter treated by sociology.
6. Ethnology is related to cultural anthropology.

Anthropology is closely related to the next area, A_7, exeligmology, and is indicated by a double circle on the border line drawn between sector Ex and sector Pr. It is briefly described later when links between areas are specifically discussed.

A_7. Exeligmology (Ex)--sciences dealing with the past

For the seventh area, the word "exeligmology" has been chosen. This word, of Greek origin, means "unfolding." This area includes sciences which deal with evolution, history, and possibly other branches of the humanities. It can be briefly described as the area which binds the sciences of history, evolution, and cosmogeny by their common objective: to outline stages of development and to remove gaps in knowledge which hinder the formation of a consistent perspective of the past.

In its broader sense, evolution as a science is the study of relations between phenomena which are brought about by time and space changes and developments. Related to the manifold aspects of development discovered by man's searching mind, the study of evolution may be regarded as the extension of history into cultural, anthropological, biological, cosmological, and other developments.

History as a science is based on collections of documents and records transmitted from generation to generation and on remnants of earlier human habitations--monuments and artifacts uncovered by archaeological research. Studies in biological evolution are based on the fossils found in geological layers deposited during long periods of existence of the earth as a planet of the solar system. Still longer eons of time were involved in the cosmic developments studied by cosmology on the basis of astrophysical evidence.

What binds together these seemingly unrelated sciences of history, evolution, and cosmogeny? It is their common objective, which consists in imaginative reconstruction of the past, in creating a picture of the stages undergone in the process of development, and in removing gaps of knowledge which hinder the formation of a plausible, consistent perspective of the past.

Each of the sciences within this seventh area has its specific subject matter. Each of them differs also in the type of evidence it seeks and in the magnitude of the time intervals it attempts to cover.

Therefore, sector Ex of the diagram shows a cluster of circles divided into three groups. Group I at the periphery consists of dark-shaded circles and represents branches of science concerned with cosmic evolution and the appearance of life, especially Homo sapiens. Group II, in the middle, consists of circles divided into a light and a dark part. These are concerned with biological and socio-historical aspects of man. Finally, Group III, closest to the center, contains clear circles which refer to the history of human culture. There is a double circle on the border line between the two sectors Ex and Pr which signifies that it is based on the past but looking into the future. It is the budding science for which the name "prognostics" seems suitable.

In Table 4. 1 branches of exeligmology are enumerated. It gives us a general picture of the development of the universe, including man and his culture.

(I.) The first division embraces exeligmology of the world at large as related to the cosmos and early forms of life. It includes cosmogeny, geogeny, biogeny, origin and development of species, and prehistory. This group of sciences is purely evolutionary in character. On the sector diagram, it is marked by dark-shaded circles.

(II.) The second division refers to exeligmology of aggregates of human beings and has two parallel subdivisions, marked on the diagram by circles divided into black and white zones. The subdivisions are as

TABLE 4. 1
EXELIGMOLOGY

I.	Exeligmology of the world at large	1.		Cosmogeny, a part of cosmology
		2.		Geogeny, a part of geology
		3.		Biogeny, a part of biology
		4.		Origin and development of species
		5.		Evolution and prehistory of *Homo sapiens*
II.	Exeligmology of aggregates of human beings	1.	a.	Evolution of aggregates of human beings
			b.	Biography of a particular individual
			a.	Evolution of a family, a part of sociology
			b.	History of a particular family, generation, or dynasty
		3.	a.	Evolution of a group (sociology and group psychology)
			b.	History of a particular group
		4.	a.	Evolution of urban, rural, and metropolitan populations.
			b.	History of a particular population
		5.	a.	Evolution of ethnical groups, as part of anthropology
			b.	History of a particular ethnical group
		6.	a.	Evolution of communities, a part of sociology
			b.	History of a particular community
		7.	a.	Evolution of states, as part of political science
			b.	History of a particular state
		8.	a.	Evolution of empires, as part of political science
			b.	History of a particular empire
		9.	a.	Evolution toward a world community
			b.	History of a particular federation of nations
III.	Exeligmology of mankind and its culture	1.		History of the development of human culture
		2.		History of the development of art and literature
		3.		History of the development of sciences
		4.		History of the development of technologies
		5.		History of the development of systems of ideas (philosophy)
		6.		History of the development of aspirations

follows:

a. the more general part, which is still essentially evolutionary in character. It studies the chain of development starting from the members of the human species, families, groups, and so on, up the rungs of the evolutionary ladder towards a world community;

b. the second part, historical in character and embracing the biography of a particular individual; the history of a particular family, generation, or dynasty; the history of a particular population,ethnical group, community, state or empire, culminating in the history of a particular federation of nations.

(III.) Finally, the third division embraces the exeligmology of mankind and its culture. It is represented on the sector diagram by clear circles.

The third division could also deal with histories of particular sciences, technologies, etc. But the latter subdivisions and other fields of history have been omitted for the sake of brevity.

It should be emphasized that Point 6, history of the development of aspirations, is evolving toward a new science--the science of the future--which I spoke of before and for which I have chosen the name "prognostics." Its aim is to eliminate the gap conspicuously separating exeligmology from pronoetics, a gap which must be filled before mankind can hope to find a solution for the present-day predicament characterized by fear and insecurity. This science is indicated by a double circle on the border line between sectors Ex and Pr. More will be said about it in the section which discusses links between the areas of knowledge.

A_8. Pronoetics (Pr)--sciences related to sustaining human life

In contrast to exeligmology, which includes all the sciences related to the past, pronoetics deals with a wide area of knowledge directed toward the future. It seeks to answer vital questions which human beings encounter throughout their active life. How does one provide for the needs of oneself, one's family, the community, the state, the country, and mankind as a whole? How do humans survive amidst the dangers they are subjected to by their inveterate enemies: hunger, exposure, illness, ignorance, aggression, boredom, degeneration, and extinction? How can one make good use of natural and human resources, so as to create conditions conducive to a more secure, healthy, and peaceful future?

The name "pronoetics" was chosen for this area because the word "pronoe," of Greek origin, denotes "foresight." Foresight, implemented by planning, is indeed the root out of which have grown the basic sciences of pronoetics:

agriculture
medicine
technology
national defense

Each of these so-called "applied sciences" has a great many subdivisions. Each seeks to utilize knowledge accumulated in the preceding areas. In return, they have all made notable contributions to the sciences in those areas by supplying new instruments, materials, and techniques of research, by collecting valuable observations, opening up new domains of experience, and raising problems for many of the parent sciences.

In Figure 4.3 the sector of pronoetics, A_8, includes six circles. Four of them represent the basic sciences enumerated above. The fifth circle is reserved for recreation as a science which studies both physical and mental recuperation from the strain of occupational activities. It is now known as occupational medicine but may become itself a basic science of this area.

Finally, the sixth circle is reserved for a new development, rapidly growing in significance but not yet sufficiently systematized to be classified as a science. It includes the auxiliary techniques which supply instrumentalities for furthering research in all the other sciences. The lack of a proper name for this prospective basic science of pronoetics makes it necessary to assign to it a temporary symbol, TAZ, an acronym made up of the first letters of the phrase "Technological Aids for Zetesis." Meanwhile it occupies a temporary place in our system of knowledge as a division of technology.

A branch of national defense which is becoming of paramount importance in our time is *pacifics*, the science of peace, more fully described later in this chapter. It attempts to discover ways for nations to live together without recourse to warfare, thus filling a wide gap in our knowledge and relating Area *Pr* to the next one, *Re*, the regulative sciences.

A_9. The regulative area (social cybernetics) (Re)

The function of this area is to study prevailing conditions and the means for harmonizing human relations for peaceful transition from past to future states of society, especially ways of balancing the distribution and exchange of the products and the services supplied by pronoetic activities.

Thus, in the ninth area, shown as sector A_9 in Figure 4.3, are included those sciences which systematize all the knowledge related to maintaining a balanced order and sustaining the degree of stability in human relations necessary for safeguarding the proper functioning of society at large. The main basic sciences in this area are as follows:

jurisprudence
political science
economics
management and administration.

The strong characteristic of this particular area of sciences is that it is concerned with systems of laws, rules, procedures, inventories, indices, and inducements which are designed to enable society as a whole to operate by balancing the multifarious activities and interests of individual groups and institutions. Whenever instability in any part of the socio-political system reaches a limit regarded as dangerous, countermeasures are, if possible, set into action in the form of social pressures and penalties which try to re-establish the disturbed balance. If the use of counter-measures is not possible, the system may be modified by complementing or changing the existing procedures or laws. In democracies, this is done by constitutional means supported by popular consent; in autocracies, by decrees.

In man-made machines, such corrective regulative measures are known as "feed-back mechanisms," and they are provided by nature in biological organisms. Studies of activities regulating technological and biological systems led to a science which was named "cybernetics" by Norbert Wiener.[*] The name is derived from the Greek word "kybernetes," meaning "steerman." Therefore, the name "social cybernetics" might be appropriate for this ninth area of sciences.

This name seems even more justified by the recent tendencies to build mechanical and electronic models which simulate economic and social conditions. Mathematicians[**] and electrical engineers[***] have suggested analogue computers for prediction, regulation, and stabilization of economic situations. All of these devices are based on the feed-back principle of cybernetics.

The connecting link which binds this area of knowledge, Re, with the next, Di, the disseminative sciences, is a branch of social cybernetics which we call "social ethics." It is concerned with setting up moral codes to orient social behavior for the harmonious functioning of human society. It differs from philosophical ethics, which is concerned with a systematic study of the ultimate problems of human conduct in relation to their moral quality.

A_{10}. The disseminative area (Di)

The most outstanding feature which distinguishes the human species from the rest of living creatures is the ability to transmit from generation to generation the knowledge accumulated throughout ages of cultural development. The transmission of knowledge has grown into an activity which requires vast and costly systems of schools, institutes, and universities, employing an ever-increasing number of teachers, librarians, writers, publishers, etc. And the individual has to spend a considerable, ever-increasing part of his life acquiring this knowledge.

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[*] Cybernetics, John Wiley & Sons, Inc., New York, 1948, p. 19.

[**] J. von Newmann, "A Model of General Economic Equilibrium," Rev. of Economic Studies, Vol. 13, No. 33 (1945-46), p. 1-9.

[***] Arnold Tustin, The Mechanism of Economic Systems, Harvard University Press, Cambridge, Mass., 1953, p. 161.

The tenth area of systematized knowledge is represented in Figure 4.3 by sector A_{10}. It contains those sciences which are related to various phases and means of disseminating knowledge, developing skills, conserving all records, and making them available for information and further research. Due to these sciences, we can enjoy and utilize our cultural heritage and continue to develop the work of our predecessors.

The basic sciences in this area are:

education
educational psychology
vocational guidance
library science
journalism
mass communication.

A still wider objective of this area is to prepare the younger generation for creative activities by developing interest and skills necessary for the growth of the arts and the sciences. Zetetic education is the science which binds sector *Di* with the next one, *Ze,* and serves to develop awareness of the unified system of arts and sciences.

A_{11}. *Zetetics (Ze)*

For modern society, increasing in population and scope, it is not enough to record and disseminate the knowledge inherited from previous generations. New problems continually arise which require more knowledge than available at present. The sciences which study how knowledge can be increased in quality and quantity are included in sector *Ze.* They are the following:

zetegeny
taxilogy
problematology
the study of zetesis
general methodology
the study of environmental conditions and incentives
education for zetesis
organization and development of research centers.

In Figure 4. 3, this emerging area of knowledge is shown as sector A_{11}, which contains circles representing the eight branches. Each of the branches studies a distinct body of subject matters. However, as a whole, the role of zetetics is to bring together and systematize available information about zetesis. Thus, zetetics binds together all the areas of knowledge, tending toward their growth and unification. It leads to the integrative area, A_{12}, which includes the study of the philosophic foundation of knowledge--epistemology. The latter represents the binding link between A_{11} and A_{12}.

A_{12}. The integrative area (In)

The culminating process in the search for what is often called "the truth" or "objective reality" is the integration of all available knowledge into one consistent system. This would represent an all-embracing synthesis which would contain not only a total picture of the world in which man lives, but also a clear understanding of his role and the aims of his activities and strivings. Such attempts are implied in zetesis.

Philosophers, prophets, and learned personalities have tried to attain such a synthesis throughout the ages, approaching the problem from various fundamentally different viewpoints. With the growth of our knowledge, this tendency has become more and more systematic and resulted in a number of sciences which may be called "integrative."

The integrative sciences may be divided into three classes, namely:

Philosophical,	which specialize in attempts to create a consistent, universal system of abstract ideas.

Aspirational,	which embrace a large variety of ideological patterns reflecting the highest human aspirations and including all the theologies.
General systems,	which study the general properties of every kind of system.

In Figure 4. 3, sector In is assigned to these sciences, and the three subdivisions are represented by three circles. The upper two refer to philosophical and aspirational sciences. Their circles are surrounded by dots to indicate the many divergent schools of thought in their respective fields. The lower circle represents general systems, a new and promising field which is attracting prominent scientists interested in the main current of modern thought.

In the early, formative years of zetetics much thought was given to the problems of the integration of human knowledge as a whole and of the place of the arts in a universal system of knowledge. Do these areas belong to spheres so radically different in character that no contacts or interrelations with the other ten areas of knowledge can be established? Our definition of science as a summary of systematized knowledge and experience growing and developing out of zetesis was derived from the various interconnections we have found to exist between all the areas. Appropriately, the arts and the integrative area represent parts of our understanding of the world in which we live. Do we not now possess, as we have possessed for ages, academies, conservatories, colleges of applied and fine arts, and also schools of divinity? Since knowledge of the development of culture is vital, these areas are included in our system. They are all linked together by zetesis--the process of creative activity which seeks to develop originality, to inspire fruitful innovations, and to stimulate tendencies toward higher and higher aspirations.

By "higher aspirations" are meant the aspirations which, predominating over all instinctive, habitual, and short-term drives, impel one toward a life work. They give orientation to one's activity in terms of goals above and beyond purely personal, economic and egocentric ambitions.

Higher aspirations play an important part in the development of individuals and in the survival of mankind as a whole. They tend to supersede tribal, ethnical, and national selfish interests and lead to the integration of all human activities toward higher levels of culture. An absence of such goals produces stagnation and disintegration in the lives not only of individuals, but of nations. Hence the significance of a systematic study of aspirations and their role in the integration of all knowledge, which we designated by the symbol K_i.

In our swift review of human knowledge, we have reached the border line separating the area of integrative sciences, In, from the arts, Ar, which was our starting point. We may now ask: Is there any specific science which connects these two adjoining areas? The answer is positive: A part of philosophy called "aesthetics" binds these two sectors together.

4. 5. Summary of Areas and Their Functions

By successive steps, aided by the sector diagram, we have succeeded in binding together the entire field of arts and sciences. We must keep in mind that the diagram represents symbolically the totality of our knowledge in a state of growth and transformation. Its dynamic quality suggests that a chain of reinforcing reactions is taking place throughout the twelve sectors of systematized knowledge in a continuous process of zetesis which tends to shape mankind's future as it evolves from the past.

We may summarize the twelve areas with the aid of Table 4. 2 in which these areas are enumerated in five series, each distinguished by its particular function.

The first series contains two areas whose function is to facilitate communication by developing systems of symbolic representation of perceptual and cognitive activity.

The second series contains four areas which supply knowledge of facts and their basic relations in the world in which we live.

The third series, grounded on the second one, embraces four areas

TABLE 4. 2
FUNCTIONS OF THE AREAS OF KNOWLEDGE

Series		Areas of knowledge	Function
I.	1.	Arts	To develop systems of symbolic representation of perceptual and cognitive activity for purposes of communication
	2.	Symbolics of information	
II.	3.	Hylenergetics	To systematize knowledge of basic facts and their relations
	4.	Biological	
	5.	Psychological	
	6.	Sociological	
III.	7.	Exeligmology	To systematize knowledge of the past, project future needs, and regulate activities
	8.	Pronoetics	
	9.	Regulative	
	10.	Disseminative	
IV.	11.	Zetetic	To promote the growth of all arts and sciences
V.	12.	Integrative	To create an all-embracing synthesis

which extend our knowledge of the past and apply the results obtained by the second series, so as to provide and build for the future while controlling the significant fluctuations ever present in a shift from past to future conditions.

The fourth series includes zetetic sciences, which are concerned with the growth of all the areas.

And, finally, the fifth series contains the integrative area, which represents attempts towards an all-embracing synthesis.

And what is the deeper meaning of the zetetic system of knowledge? It attempts to give a concise presentation of the totality of culture created by the human species: its accomplishments in the arts, its accumulated knowledge, and its heritage of aspirations. Moreover, its goal is to bring out the close connections between the various areas of the arts and sciences and suggest the direction of their growth.

The zetetic system of knowledge can also assist in the organization of education on its various levels from elementary through secondary schools and colleges.* It can serve as a guide for students, as well as for persons who are already active professionally, in choosing the roles best suited to make their lives meaningful, useful, and genuinely satisfactory. In the maze of modern life, orienting one's self, evaluating one's potentialities, determining one's goal, and finding one's proper role are becoming more and more difficult. A new approach, like the above, is urgently needed.

4.6. Lines of Influence and Links Between Sciences and Areas

In the discussion of the sector diagram which illustrates systematized knowledge from the zetetic point of view, it was mentioned that each science is represented as an expanding star-like circle. The purpose of the radial projections from the circles is to suggest lines of influence which connect the sciences with each other. These imaginary lines serve to indicate the existence of interrelations between the sciences within each sector as well as between the sciences of different sectors.

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* Democracy and Excellence in American Secondary Education, by Harry S. Broudy, B. Othanel Smith, and Joe R. Burnett, Rand McNally & Company, Chicago, 1963.

We further imagine that with the growth of knowledge the lines radiating from each expanding circle not only increase in number and vary in distribution, but even penetrate Region III and draw from there unsystematized knowledge to become systematized and unified. Thus, the dynamic properties of the zetetic system of knowledge can be envisaged.

Since it is not possible to present graphically such a complex picture of lines of influence, it was found helpful to apply here as an analogy the concepts of electrical and magnetic fields introduced by Faraday and later developed by Clark Maxwell.

In short, the lines of influence represent abstractions of communication lines which were established and represent results of the cumulative activites of numerous artists, scientists, engineers, and scholars. With the spread of culture, the totality of influences form what is often spoken of as the social atmosphere favorable for the appreciation and growth of knowledge by countless researches, publications, conferences, learned societies, etc.

In Figure 4. 2, the sector part of the diagram contains selected examples of such linking of adjacent areas (the double circles on the radial lines). Not in every case was the existence of a link self-evident; some links were derived by applying the zetetic principle of interdependence. To emphasize this aspect of taxilogy, let us first analyze in more detail the group of intersciences represented by the double circles. These sciences as enumerated in the following table are described below.

TABLE 4.3
LINKS BETWEEN AREAS OF KNOWLEDGE

Art criticism and philology	$(A_1 - A_2)$	Prognostics	$(A_7 - A_8)$
Homologic symbolics	$(A_2 - A_3)$	Pacifics	$(A_8 - A_9)$
Biophysics and biochemistry	$(A_3 - A_4)$	Social ethics	$(A_9 - A_{10})$
Physiological psychology	$(A_4 - A_5)$	Zetetic education	$(A_{10} - A_{11})$
Social psychology	$(A_5 - A_6)$	Epistemology	$(A_{11} - A_{12})$
Anthropology	$(A_6 - A_7)$	Aesthetics	$(A_{12} - A_1)$

$A_1 - A_2$. Art criticism and philology

Art criticism is one of the links which binds Areas 1 and 2. It is a form of literature and at the same time the science of judging the qualities and values of an aesthetic object related to any one of the arts. Art criticism influences public taste and gives direction to the development of the arts. Moreover, it affects the activity of artists in their choice of style, composition, and technique. Artists may appreciate objective criticism but question the ability and authority of the critics who set up standards of beauty or norms of craftsmanship which tend to stifle their free artistic activities. Out of such controversies arise new points of view and new schools of art which stimulate originality and artistic production.

Philology is still more closely related to Area 2. It studies the linguistic aspect of literature and its related forms. Some recent interpretations of philology regard it as synonymous with linguistics.

$A_2 - A_3$. Homologic symbolics

The term "homologic symbolics" has been chosen to designate that part of symbolics of information which seems to be developing as a new science linking Area 2 with Area 3.

Each new theory in any of the sciences in the hylenergetic area requires mathematical expressions which bind quantitatively the new facts into a systematic whole. A desireable "one-to-one" correspondence between the values of mathematical expression and the measurements of concrete observations is called "isomorphic." However, a one-to-one correspondence is an ideal we cannot attain and we must be satisfied with as close an approximation as possible. Therefore, we prefer to use the adjective "homologic" which implies similarity and may include linguistic or other symbolic means to represent concrete facts or processes.

Thus, homologic symbolics may be briefly described as an interscience which deals with a systematic study of descriptive or formalized means of formulating relationships between A_2 and A_3 with possible extension to other areas.

Usually an appropriate mathematical scheme for deriving such expressions is available, and it can readily be utilized for interrelating new facts or phenomena. It may happen, however, that a homologic counterpart is lacking, or buried in an old journal or treatise, as for example, in Heisenberg's search for a mathematical way to formulate his quantum mechanics. He succeeded when he envisaged an adequate method in Cayley's theory of matrices, invented sixty-seven years earlier.

In cases when an appropriate scheme is not yet available, it becomes the task of creative thought in homologic symbolics to discover it.

Mathematics has so far supplied the most needed aids for homologic symbolics, known as applied mathematics, while linguistics has supplied additions to our store of words which are made necessary by the growth of knowledge. But entirely neglected remains the need for a general consistent terminology of the arts and sciences which could lead to a more effective communication at scientific gatherings, especially at world conferences, and become the starting point for an international language. These are the most pressing problems of homologic symbolics related to applied linguistics.

A_3 - A_4. Biophysics and biochemistry

In the development of biology, it was observed that living systems have both physical and chemical aspects. Realization of this led to the rejection of the controversial vitalist concept of life as an independent entity, separate from physiochemical phenomena. As a result, we have two fast-growing sciences--biophysics and biochemistry.

Biophysics studies--among a variety of processes--blood flow, conduction of electrical impulses by the nerves, conversion of chemical into mechanical energy by the muscles, problems of vision and hearing, electro-cardiography, and many other phenomena. To its well-developed branches belong radiobiology and molecular biology.

Biochemistry, on the other hand, analyzes and synthesizes the thousands of complex chemical compounds produced within the living organisms. Thus, its main subject matters are the composition of these compounds, the structure of their macromolecules, and the role they play in living systems. Recently, a far-reaching breakthrough toward an understanding of genetic replication has been achieved.

These two sciences overlap and closely interrelate Area 3 with Area 4.

A_4 - A_5. Physiological psychology

The biological area is directly linked with the psychological area by physiological psychology, which occupies an intermediate position between neurology and psychology. It is mainly concerned with brain stimulation, brain lesions, electro-encephalography, sensory physiology, endocrine effects, psycho-pharmacology, environmental stress, and the role of genetic factors in behavior. Physiological psychology overlaps experimental psychology.

A_5 - A_6. Social psychology

Social psychology is the interconnecting link between Areas 5 and 6. Human beings live in social-cultural relations with their fellows. In their infancy their very existence depends on their families; and throughout their life cycles they are bound to their communities and to the social systems of which they are a part. The science of social psychology studies the basis of those ideas, emotions, attitudes, and habits of individuals which bind, stimulate, influence, and evoke responses from participants in a social group.

Two main aspects of this interrelation must be considered. One is how personality and cultural influences affect the behavior of the participant who has to adjust himself to the pressure of society. The other is the mass or collective aspect of men's thought and conduct which tends to stabilize or change the functioning of society.

Figure 4.4 may serve to illustrate these two aspects of social psychology. The rectangles in the upper part represent personality (P), behavior (B), and social forces (S). The action B of a person is shown to depend not only on his personality (with all its psychological traits), but also on the social forces S which influence his behavior. In the lower part of the diagram, the change of P in adjustment to the demands of his society is represented by ΔP, and the change in social forces S brought about by the mass influence of participating individuals is represented by ΔS.

We may thus look at social psychology as the science which contributes to the understanding of the dynamics and development of society.

A_0 - A_7. Anthropology

The sociological area is linked with exeligmology (A_7) by anthropology. This is a science which deals with races, tribes, families, and other groups. It started with the study of primitive peoples (extinct as well as existing) and now includes more modern societies--their ways of life, activities, beliefs, morals, customs, habits and laws.

The breadth of anthropology can be seen in its many branches and subdivisions: physical, chemical, cultural, social, and differential anthropology. Each branch is further subdivided, e.g., the cultural branch into archeology and ethnology. And in addition to all these branches, there is applied anthropology.

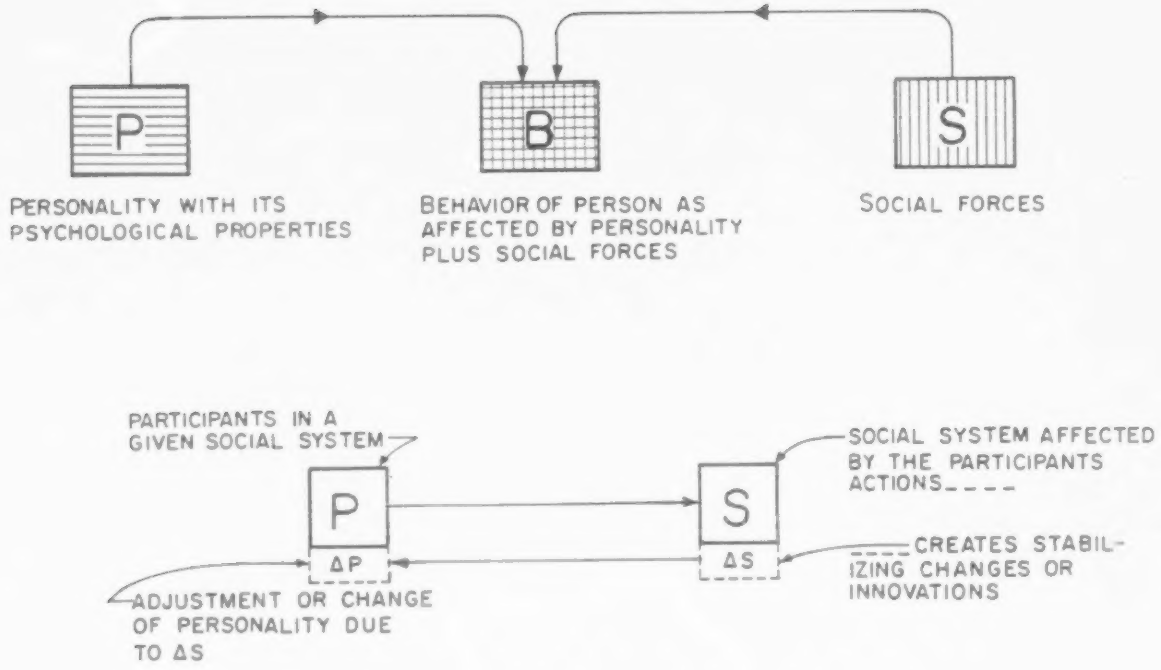
P
B
S
PERSONALITY WITH ITS PSYCHOLOGICAL PROPERTIES
BEHAVIOR OF PERSON AS AFFECTED BY PERSONALITY PLUS SOCIAL FORCES
SOCIAL FORCES
PARTICIPANTS IN A GIVEN SOCIAL SYSTEM
P
ΔP
S
ΔS
SOCIAL SYSTEM AFFECTED BY THE PARTICIPANTS ACTIONS----
----CREATES STABILIZING CHANGES OR INNOVATIONS
ADJUSTMENT OR CHANGE OF PERSONALITY DUE TO ΔS

FIGURE 4.4. THE INTERACTION BETWEEN PERSONALITY AND SOCIAL FORCES

The recent extensions of anthropology are based largely on discoveries in physical chemistry and biochemistry. Physical chemistry has contributed a method for dating objects which contain Carbon 14 or other radio-active substances. Measuring the decay of the radioactivity of lumber, hides, and other substances found in ancient places of human habitation gives a clue for dating objects as old as 15,000 years.

The contribution of biochemistry and genetics to anthropological research is blood-type analysis, which led to the discovery that the type of blood of each individual is determined by his ancestry. By dividing the population into groups according to their blood types, it is possible to discover statistically the ancestry of the population and thus to trace trends due to migrations over the years.

A_7 - A_8. Prognostics

Prognostics may serve as an example of the results of a taxilogical investigation. It was derived in an attempt to fill the gap between Area 7, exeligmology, and Area 8, pronoetics. It is a budding science based on the third principle of zetetics, the principle of controllability of the future, and it grows out of the history of human aspirations.

From antiquity up through the Middle Ages and the Renaissance, the need to glance into the future was satisfied by the occult sciences which offered oracles, horoscopes, and other mystical means for predicting the future. Nowadays, in the area of pronoetics, we possess sciences like agriculture, medicine, technology, and national defense which aim to provide knowledge for meeting the needs of the immediate future. Every action in preventive medicine, every bridge or public building, every weapon, and every attempt towards disarmament has to be planned and designed. Legislation, economics, and management are concerned with planning for the future in reaction to experiences of the past.

Similarly, education is preparation for the future. In the arts also, be it in architecture, sculpture, or dramatics, design and planning follow the imaginative phase of preconceiving the work of art and continue until the work is completed.

It is comparatively easy to plan for the immediate future, but it becomes more and more difficult when planning must be extended to the far reaches of time. We are doing pretty well in predicting the course of missiles and satellites, and also in forecasting weather and foretelling population growth and movement. But in other fields prognosis is far from satisfactory.

In literature we are witnessing the flowering of science fiction, indicating our eagerness to penetrate the veil which conceals the future. Even serious, matter-of-fact scientists write volumes depicting the coming developments. Books like "The Next Million Years" by Charles Galton Darwin, "The Foreseeable Future" by George Thomson, and essays like "The Future of Science" by Bertrand Russell are characteristic of the growing science of prognostics.

But this is just a beginning. With the increasing rapidity of change in national and international affairs, a much wider perspective and a deeper insight is necessary. Without such insight the dominant species on this planet, Homo sapiens, cannot possibly adapt itself to the rapidly changing conditions of existence and seems doomed to extinction.

The following outline is suggested for the study of prognostics:

1) The primitive practices described by anthropologists and ethnologists
2) The occult sciences and prophecies: oracles, crystal balls, etc.
3) Forecasting in modern sciences:
    a) Astronomy--precise prediction of sunrise, sunset, comets, eclipses, longest and shortest days, etc.
    b) Physics--ballistics, missiles, satellites, and weather predictions
    c) Preventive medicine--immunization against diseases and diagnoses
    d) Warfare--designing of weapons and strategic and tactical planning

e) Economics--business prospects, budgets, and projects for growth
f) Decision-making on the basis of statistics and opinion polls with the use of computers
g) Study of errors in prediction
h) Designing and planning in the arts and architecture
i) Analysis of utopias
j) Science fiction as a source of suggested innovations

The knowledge thus gained will help us to project our imagination into the future, to detect new trends, to foresee possible detrimental effects, and to control them in the interest of mankind. The objective of prognostics is not to predict the future in detail, but to analyze various possibilities; to study alternatives; to probe potentialities revealed by new conquests in the arts and sciences: and to influence coming events according to our aspirations.

We often hear the argument that history never repeats itself and is therefore unpredictable. Such is the answer of those who consider history as only a record of the past. But those who have an urge for widening the horizons of knowledge find in evolution and history certain trends indicative of what the future may have in store for us, and they search for means of consciously steering our way out of the threatening disasters.

Predictions based on trends cannot be as definite as those in the physical sciences. Nevertheless, their present vagueness does not preclude the possibility of their becoming more definite in the future. Foresight is working to find more means for controlling the evolution of man in adaptation to the new conditions which appear with accelerating rapidity. From the zetetic point of view, prognostics is an important link which binds history as the science of imaginative reconstruction of the past with the art of realistic building for the future.

A_8 - A_9. Pacifics

A link between pronoetics (Area 8) and the regulative area (Area 9) was missing until a study of sciences connected with national defense was undertaken. This study furnished another example of the usefulness of taxilogy in disclosing gaps in knowledge, for it led to the discovery of pacifics as a science.

Warfare and diplomacy are the two oldest means of national defense. But what is the object of national defense? Obviously it is to establish and maintain peace. But peace is a state of regulated stability in international relations. Do we know enough about the conditions of such stability? We found that a systematized science of peace did not yet exist.*

In the taxilogical scheme represented by Figure 4. 5, national defense is divided into three branches: warfare, diplomacy, and pacifics. Each of the divisions and subdivisions is designated according to the zetetic system of notations selected for the purpose of orientation. This system will be explained in the next chapter.

We already know much about warfare. Military science and its technology are highly developed. So is diplomacy, but very little is known about rational ways of maintaining peace. In our scheme, pacifics is divided into two branches: etiology of war and prophylaxis of war, each further subdivided. These medical terms were chosen because war may be regarded as a disease, a remnant of the primitive stage of culture when scientific ways of solving problems were unknown, and force alone was the immediate reaction to exigency. In medicine, the origin of a disease must be known before prophylactic measures can be adopted.

The etiology of war as shown in the third column is concerned with the biological, psychological, sociological, and economic causes of wars. Let us consider briefly the particular factors related to each of these causes.

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* See, however, a recent book, Towards a Science of Peace by Theo L. Lentz, Bookman Associates, Inc., New York, 1955.

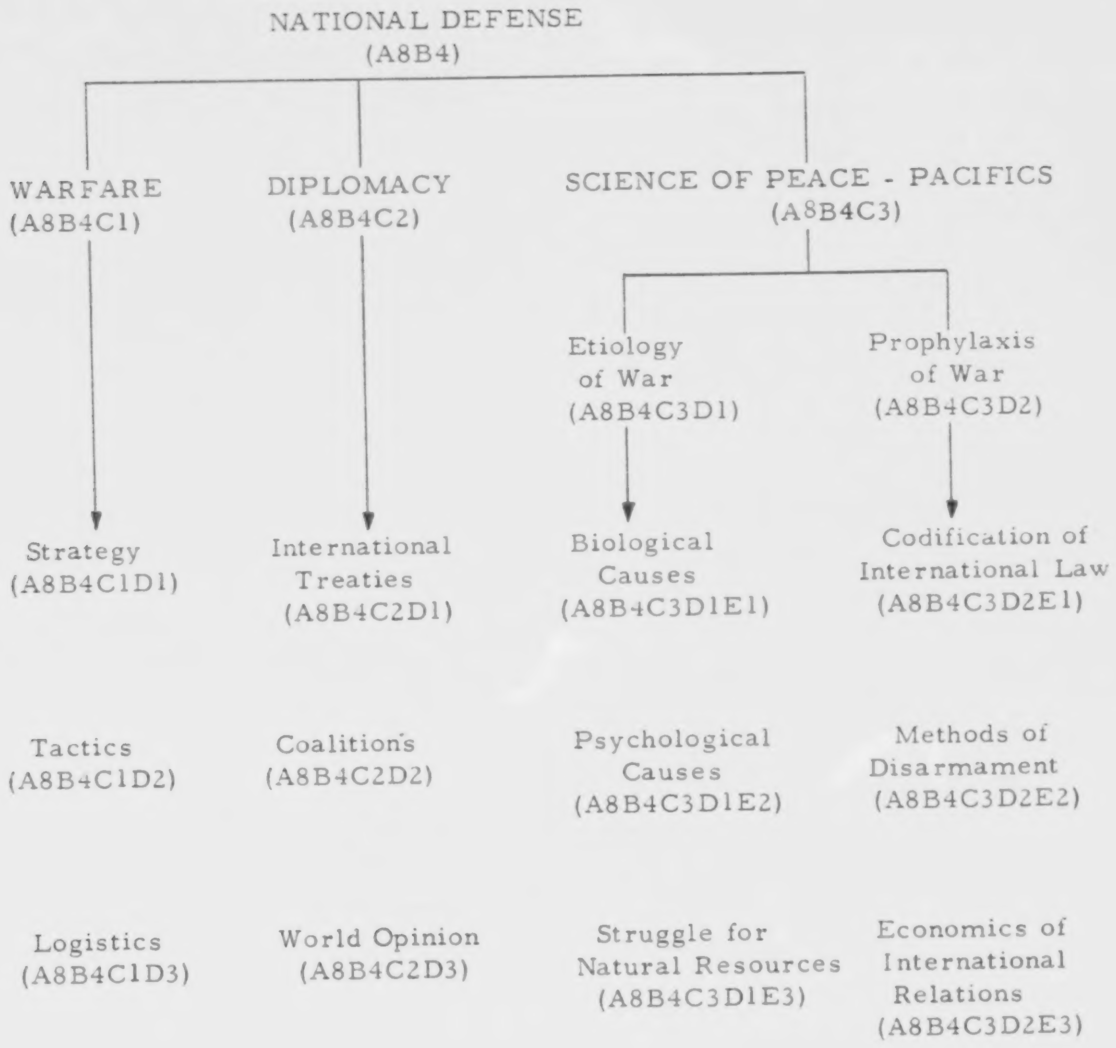
NATIONAL DEFENSE
(A8B4)
WARFARE
(A8B4C1)
DIPLOMACY
(A8B4C2)
SCIENCE OF PEACE - PACIFICS
(A8B4C3)
Etiology of War
(A8B4C3D1)
Prophylaxis of War
(A8B4C3D2)
Strategy
(A8B4C1D1)
International Treaties
(A8B4C2D1)
Biological Causes
(A8B4C3D1E1)
Codification of International Law
(A8B4C3D2E1)
Tactics
(A8B4C1D2)
Coalition's
(A8B4C2D2)
Psychological Causes
(A8B4C3D1E2)
Methods of Disarmament
(A8B4C3D2E2)
Logistics
(A8B4C1D3)
World Opinion
(A8B4C2D3)
Struggle for Natural Resources
(A8B4C3D1E3)
Economics of International Relations
(A8B4C3D2E3)

FIGURE 4. 5. TAXIOLGICAL SCHEME OF NATIONAL DEFENSE

Among the biological factors, the struggle for survival during the primitive stages of culture must have been very severe. The death of mothers in childbirth maintained a high ratio of men to women. The scarcity of women and the disadvantages of inbreeding in small isolated groups forced man to conquer weaker tribes. The consequent increase in population necessitated expansion into larger territories, often by the use of brute force.

At higher stages of human organization, the immediate results of such conquests led to a variety of psychological complications. The primitive fear of aggression was reinforced by fear of the loss of

national independence,
prestige among nations,
the freedoms guaranteed in the bills of rights,
and participation in political life

as well as by fear of

competition,
humiliation,
extinction by genocide,
forced immigration,
economic exploitation, and
encroachments in
  cultural development,
  education, especially in the use of the native language, religion, etc., and
  creativity in the arts and sciences.

In the course of development, the social and especially the political and economic organization of human groupings became more and more complex and dependent on the availability of natural resources. A struggle for such resources became increasingly imperative. Warfare for the conquest of territories, especially those rich in the black earth which produced wheat, rice, sugar, etc. became the chief preoccupation.

Far-reaching ideologies were adopted (religious, racial, social, and colonial) which attempted to justify war in one form or another--religious crusades, total war, class struggle. However, all of them had one main tendency, namely, to unify increasing populations into large-scale political organizations in the interest of providing more food, minerals, fuels, water-power, and human resources for the more powerful nation.

The human resources proved especially useful in producing on a growing scale a new kind of product, more valuable than black earth, gold, and vast territories. This new product was human knowledge, based on inventiveness and creative endeavor. It gave impetus to the development of sciences and especially to the arts and technologies. These new products proved so abundant and promising that the wildest dreams of wellbeing were exceeded by reality. The conquest of territories and subjugation of nations became unnecessary, dangerous, and degrading in view of the enormous potentialities of human creativity, which could provide for all pressing human needs and lead to a new culture on a higher level.

The fourth column of Figure 4. 5 gives the following subdivisions of prophylaxis of war: codification of international law, methods of disarmament, and economics of international relations. Our lack of systematized knowledge in these matters is becoming increasingly dangerous, since it produces stress and anxiety which hinder cultural development. The creation of an international center of research in the science of pacifics is a most urgent requirement as a preparatory step toward peace.

A_9 - A_{10}. Social ethics

The traditional way of treating ethics is to regard it as a branch of philosophy. As such, ethics is the systematic study of the ultimate problems of human conduct. Another approach is called teleological ethics, which evaluates an action on the basis of its actual or probable productivity in achieving the maximum good. It is often called utilitarianism. A modern development consists in regarding ethics as an empirical science in which ethical notions are reduced to those of the natural sciences.

In the zetetic system of knowledge a link was missing between the regulative sciences and the disseminative sciences. It is needed to bind the two areas together and is called social ethics. It is a branch of social cybernetics concerned with moral codes set up to orient social behavior for the harmonious functioning of human society.

According to our first principle--interdependence--humans from their very conception are dependent on heredity, environment, parental care, schooling, church, choice of vocation, functioning of the family, compatibility of mate, competition, ways of living, aspirations, and retirement conditions.

From this interdependence grow ties and duties to oneself, family, community, country, society, and humanity. One's actions influence the entire fabric of human existence, including one's own. Harming society means harming oneself. Benefit to society means benefit to oneself, directly or indirectly. In the long run, society cannot very well exist without the cooperation of its members in as efficient a way as possible.

Social ethics may therefore be more specifically defined as follows:

> A systematic approach to behavior by the application of social motivations, precepts, and codes for the purpose of inducing participants of a group or society of promote cooperation and to restrain from antisocial activities.

Nearly every well organized professional society has established its own code of ethics. Famous in this respect is the so-called Hippocratic oath. It contains precepts and rules accepted by the medical profession. In spite of its antiquity (460 B. C.), this oath is still taken by graduates in many medical colleges.

Many well formulated precepts have been suggested which pointedly emphasize fundamental rules of behavior. Among them are such well known ones as:

> Love thy neighbor as thy self
>
> Do not do to others what you would not like that others do to you
>
> Act in such a way that the maxim of your action could be made a universal law (the famous categorical imperative of Emanuel Kant)
>
> Act so as to achieve the maximum of happiness for the largest number of persons (the utilitarian precept).

A new approach to social ethics may be expressed by the following zetetic precept:

> Discover, develop, and use your creative abilities so that your contributions may enrich the store of knowledge and experience necessary for solving the pressing problems of humanity.

A_{10} - A_{11}. Zetetic education

As a link between the area of disseminative sciences and the area of zetetic sciences, zetetic education deals with the introduction of zetetic concepts into general education.*

Its aims are:

1. To familiarize students with the totality of the arts and sciences as a unified system.
2. To demonstrate the role of research and artistic creation in the growth of knowledge.
3. To make students aware of the treasures mankind possesses in the knowledge accumulated by the creative endeavors of past generations, and to awaken their interest in libraries, museums, and art galleries.

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* See Chapter IV by Joseph T. Tykociner in Education and the Structure of Knowledge, Fifth Symposium on Educational Research, ed. Stanley Elam, Rand McNally & Co., Chicago, 1964, p. 146.

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4. To help them envision and plan their personal role in society on the basis of their aspirations and abilities.
5. To facilitate the choice of goals and to coordinate them with their projected life's work.
6. To plan accordingly their further education.

A_{11} - A_{12}. Epistemology

The word epistemology is derived from the Greek word epistemi, meaning knowledge, and logos, meaning science.

Epistemology is the branch of philosophy which studies various theories of the origin, structure, methods, validity, and limitations of knowledge.

There are two main ways of approaching problems concerning knowledge, namely

1. empiricism, which claims that knowledge is limited to sense experiences. It means that perception is the only source of knowledge. Ideas, beliefs, or statements derived or deduced from observed phenomena are called a posteriori. They form the basis of synthetic knowledge.

2. rationalism, in contrast to empiricism, contends that knowledge, besides sense experiences, includes so-called a priori material like ideas, beliefs, or statements not derived from observation. Such material is independent of perception and based on intuition, extrasensory perception, instinct, and other sources which, it is claimed, lead to useful methods of investigation. Such a priori statements form the basis of analytical knowledge.

A_{12} - A_1. Aesthetics

The word aesthetics is derived from the Greek aisthetikos, meaning perception, especially by feeling.

Aesthetics is the study of the beautiful and of philosophical theories about it--also of the sensations and emotions evoked by objects and phenomena observed in nature or encountered in works of literature or art or in the sciences.

Its historical development was influenced by traditional philosophical rationalism and lately by empiricism, but it has not abandoned its interest in beauty, artistic value, and other normative concepts. Moreover, it lays emphasis on a descriptive, factual approach to the phenomena of art and aesthetic experience. Accordingly, we find modern inquiry in aesthetics focused on the following subdivisions:

Philosophical aesthetics, which stresses basic problems of theory as to the nature of beauty, artistic value, aesthetic experience, etc. Traditional assumptions are analyzed and criticized from the point of view of consistency with current hypotheses in philosophy and other areas of knowledge.

Comparative aesthetics, which deals with the result of observation of works of art. It compares systematically various periods, styles, and individual artists and also the various arts with one another.

Psychological aesthetics, which studies the nature of aesthetic experience; human behavior towards works of art; the processes involved in artistic production and in appreciation; the phenomena of taste and preference; and the application of the theories of empathy and psychoanalysis to art. (Empathy means: imaginative projection of one's own consciousness into another being).

Experimental aesthetics, which deals with psychological approaches to aesthetics based on measurements and on laboratory and statistical procedures. Attempts are being made to establish scales and tests for measuring ability to create and appreciate art.

Finally, sociological aesthetics, which deals with collective behavior in art appreciation and the relation of art to social, political, and economic factors.

4.7. Multiple Interrelations Between Areas of Knowledge

In searching for relations between the areas, we have so far chosen only links which bind together adjacent areas. Starting our search with the arts (Area 1), we advanced through all twelve areas and returned to the area from which we started. In doing this, we became aware that there are other links between the areas besides those which interconnect adjacent areas.

The total number of possible links is 66. This can easily be seen by adding the combinations of Area 1 and each of the other areas (11 in number), the combinations of Area 2 and each of the remaining areas (10 in number), the combinations of Area 3 and each of the remaining areas (9 in number), etc. The total number of links, N, will thus amount to the sum

$$N = 11+10+9+8+7+6+5+4+3+2+1 = 66 .$$

Combinatorial algebra supplies a generalized formula for the above, as well as for many other combinations, and does away with the necessity of a verbal description of particular cases. We shall make use of it in the next section.

The following are some of the sciences that link the arts with other areas. The link between Area 1 and the adjacent Area 2 has already been discussed. We look next for a science which connects the arts (Area 1) with hylenergetics (Area 3). Suppose that we are interested in the drawings of animals which were engraved on the walls and ceilings of caves during the Stone Age, and we want to know how old they are. Formerly their age was roughly estimated at 30,000 years. But a few years ago a method of dating artifacts was developed, based on the decay of radioactive substances, especially Carbon 14. Consequently, samples of charcoal and pigments were removed from the drawings and analyzed by this new method. The age of the pictures was thus established to be about 15,000 years. In this way, physics and chemistry from Area 3 supplied an important method for determining the dates connected with primitive arts. In modern times the optical and electronic microscopes have also disclosed to the human eye a treasure of new forms which have enabled man to envisage a wider range of possible patterns.

Next we consider Area 4, as represented by flora and fauna, and find that it has been the main source of inspiration for artists of all times. Flowers, trees, animals, and humans have furnished an inexhaustible variety of models for artistic creations. Knowledge of anatomy and physiology, and especially of the human senses, has exerted an influence on all the arts.

Further, we may look for a relation between the arts and psychology (A_1 and A_5). Is there any doubt that the creation as well as the contemplation of any work of art depends upon the mood induced by memories of past experiences? In other words, it has a psychological basis.

Similarly, we see that art has many social functions and is an important factor in social solidarity, thus connecting Area 1 with Area 6 (the social sciences).

The next area, exeligmology, is interconnected with Area 1 by the study of the history of art and of the sequence of the various periods in art.

The interrelation between Area 1 and Area 8 (pronoetics) is evidenced by the role of photography, motion pictures, television, and technology in general in the development of the arts. For instance, the conservation, restoration, and reproduction of ancient and modern art objects requires technological knowledge and skills.

The arts and regulative sciences (Area 9) are interconnected in many ways such as by the legal protection which writers, composers, designers, and others can obtain by copyrighting their works. Moreover, industrial design is becoming increasingly recognized as a method of appeal to the aesthetic sense of the buying public. In advertising, artistic approaches are gaining in importance.

The arts are interrelated with the disseminative area (A_{10}) by the applications of pictorial aids in education and mass communication.

The foremost connection of zetetics (Area 11) with the arts is the process of creativity, including education for zetesis and the environmental conditions that favor it.

Only interrelations which bind the arts with Area 12 remain. Throughout the history of mankind mythologies, religious cults, and ideologies were not only powerful sources of inspiration, but were deeply interwoven with creation of styles in architecture, sculpture, painting, music, and other forms of the arts. Thus there is a definite link between Area 1 and all of the other areas.

As further examples of multiple interrelations between areas of knowledge, let us look at Area 2, symbolics of information. In includes linguistics, mathematics, logic, and information theory and culminates in a budding interscience of homologic symbolics, discussed in the previous section. This area also is linked not only with the next one, but with all the rest of the areas. No field of knowledge is thinkable without the use of symbolic representation by spoken or written language or by mathematical or logistic systems of formalization. All the sciences of Area 2 may thus be regarded as auxiliaries which enable humans to formulate the known sciences and to grope for new ones.

Let us, for instance, consider how the development of spoken and written language assisted the growth of knowledge. From an alphabet of about twenty-five letters, words were created out of which sentences could be composed of astonishing variety of content. They can describe in detail things (concrete and imagined), phenomena, thoughts, feelings, hopes, expectations, etc. Even more wonderful is the extent to which the choice of words can be perfected so that a composed sentence can be not only meaningful, but aesthetically pleasing.

Still the richest language alone is helpless in dealing with the complex mental structures with which modern scientists and engineers operate. Hence, mathematics and the other sciences of Area 2 have to supply appropriate new tools for expanding and systematizing new knowledge. Moreover, the systematic development of language is nearly at a standstill, while most of the sciences of Areas 2 to 8 which use formalized methods are developing at an accelerating rate. They are growing much faster than sciences which depend on language alone as a means of expounding ideas.

Although the above examples include only Areas 1 and 2, similar examples can be given for any pair of areas. As was shown earlier in this section, there are a total of sixty-six interlinked pairs which form the zetetic system of knowledge.

4.8. Limitations of Knowledge

We have so far reviewed Region IV without considering the other regions. It is necessary at this stage to point out the limitations of knowledge. In attempts to gain more enlightenment, mankind is faced with two boundaries: one separating the knowlables from the unknowables (Region I); the other separating the known from an ideal integration (Region V), i.e., an all-embracing synthesis of knowledge. Both of these boundaries are set by the highest evolutionary level which Homo sapiens has so far reached.

At the first boundary, parts of the unknowables may become knowables, if the evolutionary process produces favorable mutations by change or if it is directed by conscious control. At the second boundary, reasonable progress toward integration of accumulated knowledge can be achieved by systematization, discovery of gaps, and continuous efforts toward conquering the vast unexplored territories which lie between these two boundaries. Complete integration of knowledge, like absolute truth, is an ideal. We can approach it, but hardly reach it.

4.9. Potential and Dynamic Stages of Knowledge

The zetetic system of knowledge represents a dynamic process. One of its aspects is the accumulation and amplification of knowledge, as described at the end of the introductory chapter. Another aspect is the development which converts single, disconnected observations or known facts into systematized knowledge so that they can be transposed from Region III to Region IV, to the higher level of organized sciences and their subdivisions.

To express this transmutation of unorganized into organized knowledge, two terms are needed. The term "potentially systematized knowledge" has been chosen to designate those parts of Region III which approach an embryonic stage structurally resembling Region IV, but not yet incorporated into it. For the part incorporated into Region IV, we have chosen the term "dynamically active knowledge."

Accordingly, potentially systematized knowledge is the indefinite, slumbering knowledge which the human mind is not yet fully aware of. Such knowledge cannot grow until it is released and fertilized by the creative processes of insight, imagination, and discovery of interrelations. It is analogous to the concept of potential energy in physics. Zetesis converts the potentially systematized knowledge P into dynamically active knowledge D. It can then be incorporated as a consistent part of some "known" or it can develop into a new branch of the arts and sciences which will complement the zetetic system of knowledge. If in the course of development certain additions do not fit into the zetetic system, the system will have to be modified so that it is capable of including those additions.

4.10. A System of Notations

The knowledge acquired throughout ages of development has become so extensive that an all-including, consistent system of notations must be developed prior to a systematic search for interrelations between the sciences, the arts, and their branches.

Let us denote by the symbol T the total expanse of knowledge which includes the dynamically active part D as well as the potentially systematized part P. So,

$$T = D + P.$$

$$\text{Hence, } P = T - D.$$

Both D and P are parts of one universe which possesses a common, interrelated structure. Consequently, T as a whole consists of areas to which we may assign the symbols

$$a_1, a_2, a_3, a_4, \ldots a_n.$$

To the areas of dynamically active knowledge, we have already assigned the symbols

$$A_1, A_2, A_3, A_4, \ldots A_{12}.$$

In the course of intellectual growth, knowledge becomes more and more systematized and divided into sections which are convenient to treat and to use. The faster the accumulated store of knowledge grows, the greater becomes the number of its new subdivisions. However, this tendency is counteracted by the merging of older branches.

The next taxilogical step is to designate symbols for the various subdivisions of each area. Those which form the core of an area may be considered as basic and denoted by

$$B_1, B_2, B_3, \ldots \text{and } b_1, b_2, b_3, \ldots .$$

Then come the closely related subjects, here called cognates,

$$C_1, C_2, C_3, \ldots \text{and } c_1, c_2, c_3, \ldots .$$

Further, the so-called domains (D and d), and so on.

In Table 4.4, all such symbols are systematically arranged with their tentative names and ranges. They are designed to serve as guides in assigning characteristic notations to each part of knowledge.

The names, following one another in alphabetical order, were chosen arbitrarily in an attempt to picture areas of knowledge as expanses of land decreasing in size. As to the number of subdivisions, they vary from area to area, and the number of corresponding symbols can be increased, if necessary. Nine such names were thought sufficient to cover the present need. Each of the nine successive rows from A to I represents a subdivision narrower in range than the preceding ones. While the first row (the A's) represents a vast expanse of knowledge, the last one (the I's) represents only a group of isolated observations.

Becquerel's discovery serves as an example of an isolated observation. In 1899, he found that, of the samples of various minerals which he placed on a photographic plate protected from ambient light, only one

TABLE 4.4
SUBDIVISIONS OF TOTAL KNOWLEDGE (T) : DYNAMIC (D) AND POTENTIAL (P) COMPONENTS

D	Names	Range	T = D + P
$A_1, A_2, A_3, \ldots$	Areas,	each including its basics	$a_1, a_2, a_3, \ldots$
$B_1, B_2, B_3, \ldots$	Basics,	" " " cognates	$b_1, b_2, b_3, \ldots$
$C_1, C_2, C_3, \ldots$	Cognates,	" " " domains	$c_1, c_2, c_3, \ldots$
$D_1, D_2, D_3, \ldots$	Domains,	" " " enclosures	$d_1, d_2, d_3, \ldots$
$E_1, E_2, E_3, \ldots$	Enclosures,	" " " fields	$e_1, e_2, e_3, \ldots$
$F_1, F_2, F_3, \ldots$	Fields,	" " " groves	$f_1, f_2, f_3, \ldots$
$G_1, G_2, G_3, \ldots$	Groves,	" " " heaths	$g_1, g_2, g_3, \ldots$
$H_1, H_2, H_3, \ldots$	Heaths,	" " " islands	$h_1, h_2, h_3, \ldots$
$I_1, I_2, I_3, \ldots$	Islands,	" " " isolated observations	$i_1, i_2, i_3, \ldots$

produced a visible image when the plate was developed. This single, isolated observation led to more facts and marked the beginning of a new branch of physics--radioactivity.

Table 4.4 indicates the notated patterns of knowledge and suggests its two additional dynamic aspects: one, directed downward from A to I, tends to increase the number of specialties entering the sphere of knowledge and leads to new subdivisions: the other, directed upward from I to A, tends to unify and synthesize the subdivisions.

Table 4.5 shows some basic sciences and their notations as they are derived from the symbols enumerated in Table 4.4.

So far comparatively simple examples of notations have been given. However, the complexity of notations increases with more complex types, especially if they represent a combination of various basic sciences which stem from more than one area.

Thus, we can distinguish three structural types of sciences, which can be characterized as follows:

TABLE 4. 5
EXAMPLES OF NOTATIONS

Symbolics of information	A_2
Linguistics	A_2 B_1
Mathematics	A_2 B_2
Logic	A_2 B_3
Information theory	A_2 B_4
Hylenergetics	A_3
Physics	A_3 B_1
General theoretical physics	A_3 B_1 C_1
Classical mechanics	A_3 B_1 C_1 D_1
Gravitation and relativity	A_3 B_1 C_1 D_2
. . . .	. . . .
Physics of the solid state and its phases	A_3 B_1 C_2
Mechanics of rigid and deformable bodies	A_3 B_1 C_2 D_1
. . . .	. . . .
Molecular physics	A_3 B_1 C_3
Statistical mechanics of molecules	A_3 B_1 C_3 D_1
. . . .	. . . .
Atomic Physics	A_3 B_1 C_4
Statistical mechanics of atoms	A_3 B_1 C_4 D_1
. . . .	. . . .
Chemistry	A_3 B_2
Chemical taxonomy and nomenclature	A_3 B_2 C_1
Classification (periodic) of elements	A_3 B_2 C_1 D_1
. . . .	. . . .
Biological area	A_4
Botany	A_4 B_1
Zoology	A_4 B_2
Taxonomy	A_4 B_3
Taxonomy of plants	A_4 B_3 C_1
Taxonomy of animals	A_4 B_3 C_2
. . . .	. . . .

TABLE 4. 5 (CON'T)
EXAMPLES OF NOTATIONS

Exeligmology	A_7
Exeligmology of the world at large	$A_7\ B_1$
" " aggregates of human beings	$A_7\ B_2$
" " mankind and its culture	$A_7\ B_3$
Pronoetics	A_8
Agriculture	$A_8\ B_1$
Medicine	$A_8\ B_2$
Technology	$A_8\ B_3$
National defense	$A_8\ B_4$
Warfare	$A_8\ B_4\ C_1$
Diplomacy	$A_8\ B_4\ C_2$
Pacifics	$A_8\ B_4\ C_3$
Regulative area	A_9
Political science	$A_9\ B_1$
Jurisprudence	$A_9\ B_2$
Economics	$A_9\ B_3$
Management	$A_9\ B_4$
Zetetics	A_{11}
Zetegeny	$A_{11}\ B_1$
Taxilogy	$A_{11}\ B_2$
Problematology	$A_{11}\ B_3$
Zetesis	$A_{11}\ B_4$
General methodology	$A_{11}\ B_5$
Environmental conditions	$A_{11}\ B_6$
Education for zetesis	$A_{11}\ B_7$
Research centers	$A_{11}\ B_8$

1) A homogeneous science stems from only one area, e.g.

mathematics	A_2B_2
physics	A_3B_1
zoology	A_4B_2

2) An endogenous science originates by merging parts of two or more basic sciences of the same area, for instance

astrophysics	$A_3B_1B_3$
physical chemistry	$A_3B_1B_2$
geochemistry	$A_3B_2B_4$

3) A heterogeneous science stems from two or more sciences related to two or more areas. The following examples of heterogeneous sciences are listed in the order of their increasing complexity:

metallography	$A_3B_nA_8B_3C_n$ (two areas)
acoustical engineering	$A_3B_1C_nA_8B_3C_n$ (two areas)
serology	$A_3B_2C_nA_4B_nA_8B_2C_n$ (three areas)

The subscript n means that definite numbers for these particular basics and cognates have yet to be assigned.

At this point it may be well to describe how our form of notation can be modified to serve even the most complex combinations of sciences. Suppose we have an imaginary science composed of several interrelated subject matters derived from three different areas.

A_1 contributes one basic B_2
A_2 contributes one basic B_1 + one cognate C_2 + one domain D_1
A_3 contributes one basic B_2 + one cognate C_3

The notation for this science would look as follows:

$$A_1B_2A_2B_1C_2D_1A_3B_2C_3 \tag{1}$$

Much space is required for this form. To shorten it, indexes can be used, namely, exponents for the areas and subscripts for the basics and their subdivisions. Thus we obtain

$$B_2^1\ B_1^2\ C_2^2\ D_1^2\ B_2^3\ C_3^3 \qquad (2)$$

This is the shortest way, but very difficult to type. It was, therefore, decided to indicate the areas and their subdivisions by subscripts according to the first notation as we have done so far throughout this outline. It might also be feasible to leave out the A for area and use only the number of the area on the line, which would give the following:

$$1B_2 2B_1 C_2 D_1 3B_2 C_3 . \qquad (3)$$

In case it is desirable to get easy-to-perceive notations at the expense of printing space, we might enclose the basics, cognates, etc. of each area together inside parentheses, and write their indexes on the line, thus:

1(B2)2(B1C2D1)3(B2C3). (4)

4.11. Zetetic Tables and CDP Lists of the Arts and Sciences

The compilation of names of sciences, technologies, and their subdivisions was a time-consuming task which continued for years. The main sources for this purpose were general and special dictionaries, catalogs of university courses, and indexes of scientific journals.

From this material a card catalog was prepared with the names of the sciences and brief discriptions of them arranged in alphabetical order. These cards are continuously supplemented and, together with a typewritten catalog, represent an inventory of the arts and sciences.

The next step was to devise a practical procedure for assigning a notation to each science so that it could be easily identified and properly tabulated. Although the model of the periodic table of chemical elements was considered, it could hardly be applied to these tables because of the much larger number and the entirely different character of the entities.

The system of notation finally adopted was described in the previous section. According to this system, knowledge is divided into twelve areas, each of which is again divided into basics, and these are subdivided into cognates, etc. Therefore, in treating the inventory of sciences, we can tabulate all the sciences in alphabetically ordered lists. Let us call such tabulated lists "zetetic tables." Their special role is to serve as a guide in search for interrelations between as yet disconnected parts of knowledge.

Depending on whether the sciences are ordered by areas alone, or by areas and basics, or by adding to the latter more specific divisions, like cognates and domains, we obtain a primary zetetic table, a secondary zetetic table, a tertiary zetetic table, etc.

In the preparation of the tables, the first step was to mark on each of the catalog cards a symbol to denote the area (A_1 to A_{12}) to which this particular science belongs. Thus, the primary table consists of twelve columns headed A_1, A_2, A_3, etc. up to A_{12}. Each row of the table consists of the name of a science and one or more symbols indicating the areas to which it belongs. This table serves to divide all items into twelve groups, each containing the sciences which belong to a particular area or to a combination of two or more areas. For convenience in typing and printing, the primary zetetic table of sciences was divided into pages, each page with a column of twenty-five. A sample page of this table (Table 4.6) follows. It lists sciences from tensor analysis to aquiculture and indicates the various areas to which they belong.

Next twelve secondary tables were designed, one for each area. Thus, a secondary table contains all the sciences in alphabetical order belonging to one particular area. The left-hand column gives the name of each science, the second column the symbol for its basic, B_1, B_2, B_3, etc., and the third column a notation for the area and basic. A sample page from a secondary zetetic table is shown in Table 4.7.

To draw up tertiary tables, we would take the basics of each area in their numerical order (first B_1, then B_2, B_3, etc. of Area 1; next the basics of Area 2; and then the basics of other areas) and arrange the sciences which fall under each basic in their alphabetical order. The next column would indicate the cognate under which each science is subsumed.

To get the quaternary tables, the sciences belonging to the cognates of each area would be taken in alphabetical order under each cognate, and

TABLE 4.6
SAMPLE PAGE FROM THE PRIMARY ZETETIC TABLES

Sciences	Areas											
	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}
ANALYSIS, TENSOR		A_2										
ANALYSIS, VECTORIAL		A_2										
ANALYTICS		A_2										
ANATOMY				A_4								
ANATOMY, COMPARATIVE				A_4								
ANEMOLOGY			A_3									
ANEMOMETRY			A_3					A_8				
ANESTHESIOLOGY				A_4				A_8				
ANGIOGRAPHY				A_4				A_8				
ANGIOLOGY				A_4				A_8				
ANTHROPOGENY						A_6	A_7					
ANTHROPOGEOGRAPHY						A_6	A_7					
ANTHROPOLOGY						A_6	A_7					
ANTHROPOLOGY, APPLIED						A_6	A_7					
ANTHROPOLOGY, CHEMICAL			A_3			A_6	A_7					
ANTHROPOLOGY, CRIMINAL						A_6	A_7					
ANTHROPOLOGY, CULTURAL						A_6	A_7					
ANTHROPOLOGY, DIFFERENTIAL						A_6	A_7					
ANTHROPOLOGY, PHILOSOPHICAL						A_6						A_{12}
ANTHROPOLOGY, PHYSICAL			A_3			A_6	A_7					
ANTHROPOMETRY						A_6	A_7					
ANTHROPONOMY					A_5		A_7					
ANTHROPO~~R~~SOPHY												A_{12}
APICULTURE								A_8				
AQUICULTURE								A_8				

TABLE 4.7
SAMPLE PAGE FROM THE SECONDARY ZETETIC TABLES

SCIENCES	BASICS				NOTATION
AREA 8	B_1	B_2	B_3	B_4	
PSYCHROMETRY			B_3		A_8B_3
PYELOGRAPHY		B_2			A_8B_2
PYRETOLOGY		B_2			A_8B_2
PYROMETRY			B_3		A_8B_3
PYROTECHNICS			B_3		A_8B_3
RADAR ENGINEERING			B_3		A_8B_3
RADIO ENGINEERING			B_3		A_8B_3
RADIOGRAPHY			B_3		A_8B_3
RADIONICS			B_3		A_8B_3
RADIOMETRY		B_2			A_8B_2
RADIOPHOTOGRAPHY			B_3		A_8B_3
RADIOSCOPY			B_3		A_8B_3
RADIOTELEGRAPHY			B_3		A_8B_3
RADIOTELEPHONY			B_3		A_8B_3
RAILWAY ENGINEERING			B_3		A_8B_3
REFRACTOMETRY			B_3		A_8B_3
REFRIGERATION ENGINEERING			B_3		A_8B_3
RETINOSCOPY			B_3		A_8B_3
RHEUMATOLOGY		B_2			A_8B_2
RHINOLOGY		B_2			A_8B_2
RHINOSCOPY		B_2			A_8B_2
ROCKETRY			B_3		A_8B_2
ROENTGENOLOGY		B_2			A_8B_2
SANDICULTURE	B_1				A_8B_1

the center column would represent the domain, D_1, D_2, D_3, etc. The same process could be repeated for further divisions of the sciences into enclosures, E_1, E_2, E_3, etc., and fields F_1, F_2, F_3, etc.

Still other sets of tables are being designed for grouping sciences and their branches as homogeneous, endogenous, and heterogeneous. Such subdivisions should be useful in perceiving gaps; for, starting with the simplest notations of the homogeneous group, we can proceed to an inspection of the more complicated notations of the endogenous and heterogeneous groups.

In addition to the above tables, so-called CDP lists will be used. The symbol CDP is an acronym of the words "Combinatorials of Dynamic and Potential," which signifies that the list includes combinations of notations pertinent to dynamically active (D) as well as potentially systematized parts of knowledge (P). This list, compiled by computer and printed in small letters, will contain rows of combinations referring to areas (a's), basics (b's), cognates (c's), etc.

4. 12. Examples of the Results of Searching for Interrelations

TECHNOLOGICAL AIDS TO ZETESIS

In the development of any science, an important role is played by measurement and observation. In early times, few measurements could be made; but as instruments improved in quality and variety, greater precision and speed could be obtained. What was originally part of the art of research became a technique which does not now require either the skill or the expertness formerly necessary to operate such instruments or special equipment.

The question now arises whether such techniques such as, for instance, thermometry, spectroscopy, and cardiography are to be regarded as parts of the science from which they evolved or rather as a distinct zetetic technology. The latter seems a more suitable description for such activities. This view is supported by the observation that in the first four areas the demand for instruments and special technical equipment is increasing so fast that technology has had to take over the production and further development of these auxiliary tools of research. This particular tecnhology is growing rapidly into an independent branch of pronoetics. As an acronym for Technology of Aids to Zetesis, TAZ has been chosen.

> This branch of pronoetics may be defined as: the application of various sciences to the production and development of means for facilitating research and artistic creation. It includes instrumentation and all techniques for observation, measuring, recording, computing, and sorting data. In connection with artistic creation, for instance, aids like the kaleidoscope, pantograph, and color analyzer may be mentioned.

To maintain a rational classification in our inventory of sciences, it seems best to separate some of the subdivisions of sciences whose names end with the suffixes *scopy*, *metry*, and *graphy* from their parent sciences and to list them as cognates of technology. There are about one hundred and fifty items so listed in the inventory of sciences. However, every technique will have to remain part of the particular science which gave it birth so long as this technique is not used in other sciences, does not require any specialized skill or expertness to apply it, and is not yet embodied in manufactured equipment. This criterion will have to be considered in assigning numbers to the cognates added to the sciences listed in Table 4.7.

However, if this branch of technology continues to grow as fast as it has been growing in recent years, a time may come when it will be necessary to separate it from technology and treat it as a special science. Then the problem will be: Should it go in the area of pronoetics, as a basic science parallel to agriculture, medicine, technology, and defense? Or should it rather be included in the area of zetetics, parallel to zetegeny, taxilogy, problematology, and general methodology? In the meantime we may be satisfied with TAZ as a branch of technology.

TAXILOGICAL SCHEME OF INTERRELATIONS BETWEEN SYMBOLICS OF INFORMATION AND TECHNOLOGICAL AIDS TO ZETESIS

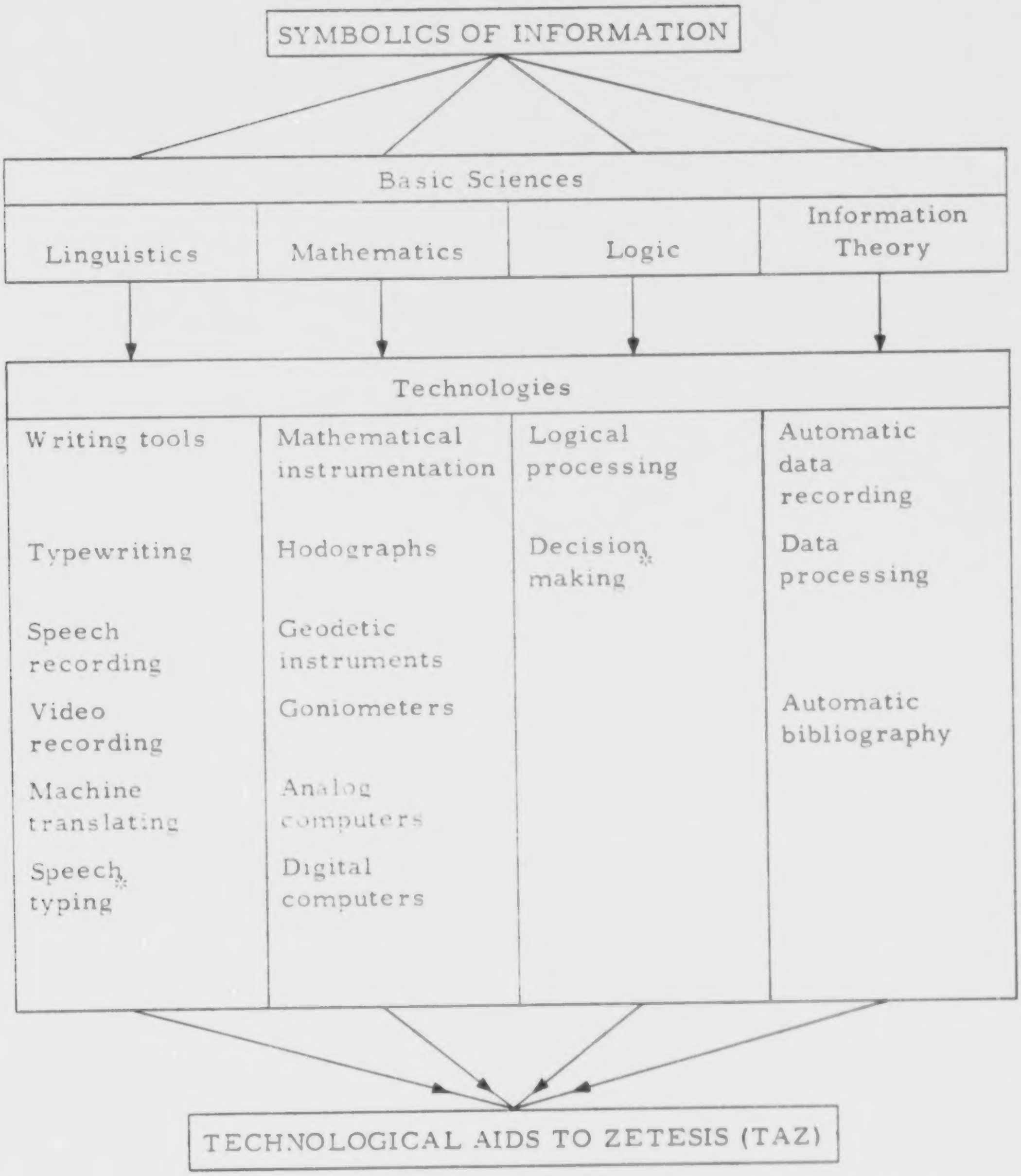
As an example of the relation of TAZ to an area, let us see how it is related to the second area of knowledge (symbolics of information). At a casual glance, this area appears far removed from the concrete products of technology, for it deals predominately with symbols. Nonetheless, our ever-present desire to economize time and effort has brought amazing consequences to this area.

As presented in Figure 4.6, Area 2 has four basic sciences: linquistics, mathematics, logic, and information theory.

In the field of spoken and written language, the sounds produced by our organs of speech were probably the first means of communication. But sound is evanescent. For permanency,writing had to be invented, first by the use of a stylus on a surface of clay or wax tablets and then by pen and ink on parchment or papyrus. Copies could be made only by scribes, and that required much time and manpower.

Later technology brought printing with its presses, rotating machines, and linotypes. Stenography had earlier been invented to record public debates; typewriting was added to facilitate correspondence and as an aid in accountancy. Considerable progress was made when the sounds of speech could be directly recorded without the intervention of an alphabet. Still greater progress was attained by video recording. An even wider perspective has been revealed by the development of the so-called machine languages (or codes) nowadays used in connection with digital computers and in automatic translation from one language into another. It can be clearly foreseen that in the not too far distant future speech-typing will be realized, transferring speech directly into type.

As to the science of logic, it already has its technology of processing, in the form of logical machines which have become parts of a large group of computers. The existing chess-playing machines, in spite of their


SYMBOLICS OF INFORMATION
Basic Sciences
Linguistics
Mathematics
Logic
Information Theory
Technologies
Writing tools
Typewriting
Speech recording
Video recording
Machine translating
Speech* typing
Mathematical instrumentation
Hodographs
Geodetic instruments
Goniometers
Analog computers
Digital computers
Logical processing
Decision* making
Automatic data recording
Data processing
Automatic bibliography
TECHNOLOGICAL AIDS TO ZETESIS (TAZ)

* These items are not yet in existence. They represent gaps in technology.

FIGURE 4.6. INTERRELATION BETWEEN SYMBOLICS OF INFORMATION AND TECHNOLOGICAL AIDS TO ZETESIS (TAZ)

limitations, foreshadow the coming of decision-making devices.

Turning our attention to mathematics, we find that a variety of instruments have appeared which perform intricate tasks quickly and accurately--for instance, planimeters, hodographs, goniometers, geodetic instruments, and many types of computing devices which have culminated in the development of analogue and digital computers.

And what is the contribution of technology to the utilization of the fourth basic science of this area, information theory? A large number of machines have recently been developed for the purpose of recording and processing data. An electronic device automatically compiles bibliographies and thus facilitates retrieval of information needed in research.

Thus, if we draw up a list of the basic sciences of symbolics of information and their corresponding technological aids, as shown in Figure 4.6 we find an interesting relation between them based on their mutual reinforcement. We may call the techniques for this particular area "the technological aids for symbolics of information."

By the use of similar presentations for other areas of knowledge--hylenergetics, biological sciences, etc.--we can picture their respective technological aids. Such aids are being applied for many purposes, but they are especially useful to zetesis, since they accelerate the production of new knowledge. This is why we are using the collective name "Technological Aids to Zetesis (TAZ)."

TAXILOGY RELATED TO MORPHOLOGY IN GASEOUS ELECTRONICS

The following may serve as the third example of the fruitfulness of taxilogy. For many years electrical phenomena in gasious electronics were investigated at the University of Illinois.* Under certain definite conditions striae were found to appear; they glow in beautiful colors and often resemble the northern lights. Phenomenological investigation led to the discovery of other forms of glow--spherical, elliptical, or ring-shaped, depending on gas pressure, magnetic field, and applied electric potential.

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* J. T. Tykociner, "Striations and Magnetic Effect in Electrodeless Discharges," Physical Review, Vol. 33 (1930), p. 1436.

In trying to determine taxilogically the place of this field of gaseous electronics, one becomes aware of a gap in our knowledge of electric discharges which prevents us from interrelating the above phenomena with other properties of plasmas. It seemed proper that the term "morphology of electric discharges" be used to designate all such phenomena as a branch of gaseous electronics, one part of which--magnetically contained plasmas--is already becoming very important in connection with the utilization of atomic power.

The ionospheric layers enveloping the earth as well as the Van Allen radiation belt may be regarded as part of morphology of ionized gases. In still another field--astrophysics--morphologic phenomena which take place on the sun's surface are being studied by Harold Larin and Robert Leighton at the California Technological Institute. Time-laps motion picture photography reveals the existence of undulating "landscapes" with forest-like fiery jets of electrified gas and gigantic waves, hundreds of kilometers high and thousands of kilometers long, rolling over the solar surface.

In accordance with the notations given for physics, the taxilogical place for this field in the inventory of sciences was established, namely $A_3B_1C_5D_3E_n$, where

A_3 stands for the area - hylenergetics
B_1 stands for the basic - physics
C_5 stands for the cognate - electronics
D_3 stands for the domain - gaseous electronics
E_n stands for the enclosure - morphology of electric discharges.

By thus incorporating the enclosure E_n, morphology of electric discharges, into the interrelated group of physical phenomena, a gap in our knowledge of gaseous electronics has been delineated for investigation.

INTERRELATIONS BETWEEN SCIENCES OF THE REGULATIVE AREA A_9

A fourth instance of the usefulness of taxilogy was found in defining the position of political science, jurisprudence, economics, management, and administration in the zetetic system of knowledge. It is characteristic of all these sciences that most of the phenomena they study appear to be transients, or even surges, which continue for comparatively short intervals of history. Some of them, like depressions, political upheavals, and consititutional crises, last for only a few years. Others, resulting from technological inventions or shifts of population, last for a generation or two, but seldom does their full strength extend over more than fifty years. Does this not resemble the reactions produced by technological devices and biological organisms in their attempts to readjust themselves to new conditions and to swing in various directions until a new equilibrium is achieved? It is, therefore, logical to take the above sciences out of the area of the social sciences and to incorporate them into a new, regulative area (A_9) as described in Section 4. 4. The name "social cybernetics" has already been mentioned as a possible alternate name for this area. Thus, taxilogical considerations led to a new division of sciences and to a fresh outlook as to their role.

INTERRELATIONS BETWEEN AREAS 7 AND 8

Of interest here is the gap which was disclosed by attempts to bridge exeligmology (A_7) and pronoetics (A_8). A new science, prognostics, had to be formulated to fill this gap, as described in Section 4. 7.

TAXILOGY AND NATIONAL DEFENSE

Finally, the taxilogical analysis of the sciences in the field of national defense may be referred to as an example of a scheme which led to a new science, pacifics, described in Section 4. 7.

4. 13. General Procedure for Locating Gaps in Our Knowledge

The examples described in the previous section show how the search for interrelations between areas and between sciences within an area leads to the discovery of significant gaps in our knowledge.

So long as we are concerned with a small number of closely related sciences, we can search for gaps by taking up, one by one, narrow fields which appear to be of interest. In this way, however, we risk missing important interrelations. Thus the question arises: how can we proceed in order to be sure that the search is thorough and sweeps over as wide a realm of knowledge as possible?

Research can be looked upon as an activity aimed at the wresting of knowledge from the vast expanses of ignorance. Thus, zetetics becomes an area of knowledge whose object is to study the strategy and tactics in the struggle for enlightenment. In this struggle, every glimpse we can get into the unknown should prove useful. One of the approaches consists in a systematic search for interrelations between fragments of the known. Let us, therefore, start from the simple theoretical considerations which led to a method of locating gaps in the partly systematized knowledge by means of combinatorial mathematics.

In Section 4. 10 of this chapter, two kinds of symbols were considered for notating areas, sciences, and their subdivisions. One kind, capital letters, was assigned to the known, the dynamically active or briefly the dynamic (D) knowledge. The other kind, small letters, was assigned to the total systematized knowledge (T), which includes both dynamic and potentially systematized knowledge (T = D + P).

On the basis of the principle of interdependence, which covers both the known and the as yet unknown, we are justified in assuming that the zetetic system of knowledge symbolized by the sector diagram Figure 4. 2 and Table 4. 4 applies not only to the known, i. e., dynamically active D, but also to the as yet unknown but potentially systematized knowledge P. Consequently, we are also justified in applying combinatorial mathematics to the total systematized knowledge T by operating with small letters.

With this in mind we obtain the so-called CDP lists of Combinatorials of Dynamic and Potential knowledge described at the end of Section 4. 11. Each of the combinations included in the CDP list corresponds to a specific pattern expressed symbolically by its notation. Translated into a combination of areas, basics, cognates, etc., each such notation indicates a specific part of systematized knowledge without disclosing its D or P type.

Here the question arises: how can the two kinds (D and P) be distinguished from each other? The answer is very simple, indeed. If a given combination in the CDP list corresponds by its notation to any of those compiled in capital letters in the zetetic tables, it is of the D type and consequently indicates a known part of our knowledge. If however, inspection of the zetetic tables does not reveal a corresponding notation, we conclude that it represents a P type, a part of our knowledge of which we are not yet aware. Consequently, we must subject it to investigation. The notation attached to it gives us valuable clues; it tells us to what area, basic, cognate, and other subdivisions the as yet unknown belongs. We check first of all to be sure that the particular notation was not left out of the zetetic tables through a mistake or omission. If this is not so and we are intrigued by its possible significance, we will be inclined to initiate pertinent research projects.

APPLICATION OF COMBINATORIAL ALGEBRA

For the following problem combinatorial algebra gives a general answer from which a numerical answer can be obtained: given a set of n terms, expressed in integers which may represent anything (areas, basics, cognates, etc.),

$$1, 2, 3, \ldots \ldots \ldots \, n, \qquad (1)$$

how many combinations can be obtained?

The following expression serves for calculating the number of combinations C where r is the number of terms taken at a time.

$$_nC_r = \frac{n!}{r!\,(n-r)!} \qquad (2)$$

For a concrete case, let us take n = 12, each term representing an area of knowledge.

$$a_1, a_2, a_3, \ldots\ldots\ldots a_{12} \tag{3}$$

Expression 2 gives the following values for C:

For r = 1, C = 12 singles
" r = 2, C = 66 doublets
" r = 3, C = 220 triplets
" r = 4, C = 495 quadruplets
" r = 5, C = 792 quintuplets
" r = 6, C = 924 sextuplets
" r = 7, C = 792 groups of 7
" r = 8, C = 495 groups of 8
" r = 9, C = 220 groups of 9
" r = 10, C = 66 groups of 10
" r = 11, C = 12 groups of 11
" r = 12, C = 1 group of 12

Number of possible combinations $C_t = 4095$

Generally, this total number is given by the expression

$$C_t = 2^n - 1. \tag{4}$$

Each of the above combinations, except the singles, symbolically represents various areas which already are or may eventually be interconnected by one or more sciences. The first instance (r = 1) has to do with singles. It means that each of the twelve terms stands isolated without any relation to the others. To interrelate areas, we must have at least two. The second instance (r = 2) deals with 66 doublets. This means that, by juxtapositioning the twelve terms in pairs, we can arrange them in 66 different ways.

In our search for interrelations, we first selected the doublets of adjacent areas:

a_1-a_2, a_2-a_3, a_3-a_4, a_4-a_5, a_5-a_6, a_6-a_7,

a_7-a_8, a_8-a_9, a_9,a_{10}, a_{10}-a_{11}, a_{11}-a_{12}, and a_{12}-a_1.

In looking over our inventory of the arts and sciences we found that only in eight of the above cases did one or more known sciences interconnect two adjacent areas. Those sciences were

Art criticism and philology,	linking	A_1 to A_2
Biophysics and biochemistry,	"	A_3 to A_4
Physiological psychology,	"	A_4 to A_5
Social psychology,	"	A_5 to A_6
Anthropology,	"	A_6 to A_7
Social ethics,	"	A_9 to A_{10}
Epistemology,	"	A_{11} to A_{12}
Aesthetics,	"	A_{12} to A_1.

Since the above sciences were found to be known, their notations are written in capital letters.

We found no connecting sciences for the other four pairs of adjacent areas. Therefore, the lacking links had to be regarded as yet unknown, but potentially systematized, parts of knowledge. Subsequent research led to four new sciences, which were then formulated, included in our inventory of arts and sciences, and assigned capital letters to replace the small letters. These new sciences are as follows:

Homologic symbolics,	linking	A_2 to A_3
Prognostics,	"	A_7 to A_8
Pacifics,	"	A_8 to A_9
Zetetic education,	"	A_{10} to A_{11}.

They are described in Section 4.6 of this chapter.

To understand the above procedure, it is important to notice that so long as the links are unknown, small letters are used for our notations. The small letters are replaced by capital letters as soon as the unknown sciences become identified with already known or newly discovered ones. In this way the distinction between the known and the as yet unknown sciences is stressed.

The above description related merely to the adjacent areas and represents only one of the steps of the method for detecting gaps in our knowledge. It will require much effort to determine the links between all the 66 doublets calculated for $r = 2$ in Equation 2. Then in a similar way we may continue to investigate the triplets, quadruplets, etc., until we discover the most significant link--the one connecting all twelve areas--a prerequisite for the integration of the arts and sciences of all the areas.

Of course, with the discovery of new arts and sciences the number of fruitful combinations will increase. They in turn will have to be subjected to investigation and will ultimately be incorporated into the zetetic system of knowledge.

Let us briefly describe still another step in our procedure. It concerns interrelations between the basics within any area. The set of terms (Expression 1) will in such a case be written

$$b_1, b_2, b_3, \ldots b_n. \qquad (5)$$

To simplify our task, we will limit our choice to the basics of one particular area at a time--for instance, an area which contains only four basics. The number of combinations calculated from Equation 2 for $r =$ 1, 2, 3, and 4 respectively is as follows:

For $r = 1$,	b_1	b_2	b_3	b_4	${}_4C_1 = 4$ singles
For $r = 2$,	b_1b_2 b_2b_3	b_1b_3 b_2b_4	b_1b_4 b_3b_4		${}_4C_2 = 6$ doublets
For $r = 3$,	$b_1b_2b_3$	$b_1b_2b_4$	$b_1b_3b_4$	$b_2b_3b_4$	${}_4C_3 = 4$ triplets
For $r = 4$,	$b_1b_2b_3b_4$				${}_4C_4 = 1$ quadruplet
					$C_t = 15$ combinations

In this case, the total number of combinations amounts to 15 and is in agreement with Equation 4.

$$C_t = 2^4 - 1 \qquad (4)$$

In order to facilitate and to check the enumeration of combinations for most of the cases occurring in our work, the values ${}_nC_r$ and C_t were calculated for n = 1 to 6 and for r = 1 to 6, using Equations 2 and 4. The tabulated values thus obtained are shown in Table 4. 8 to indicate how the number of singles, doublets, triplets, etc., and the total number of combinations increase with an increase in the number of items n.

TABLE 4. 8
NUMBER OF COMBINATIONS FOR

$${}_nC_r = \frac{n!}{r!\,(n-r)!}$$

	Singles	Doubles	Trip.	Quad.	Quin.	Sext.	Total number of combinations
n r	1	2	3	4	5	6	$C_t = 2^n - 1$
1	1						1
2	2	1					3
3	3	3	1				7
4	4	6	4	1			15
5	5	10	10	5	1		31
6	6	15	20	15	6	1	63
	21	35	35	21	7	1	120

In the above table we were concerned with combinations within one area. By applying the same procedure to other areas, we extend correspondingly the number of possible combinations. So, for instance, Table 4. 9 contains notations for five areas A_1 to A_5. For each of them a certain number of basics (b-items) are chosen, namely, n = 5, 4, 6, 4, and 5. The calculated number of combinations of basics is tabulated for each area in the last column.

The last column shows how the total number of 155 combinations is distributed among the areas, while in the last line are summed up the number of singles, doublets, triplets, etc. in the five areas.

TABLE 4.9

COMBINATIONS OF SCIENCES WITHIN EACH OF THE FIRST FIVE AREAS

Area	Basic Sciences	Sing.	Doub.	Trip.	Quad.	Quin.	Sext.	$_nC_r$
a_1	b_1, b_2, b_3, b_4, b_5	5	10	10	5	1		31
a_2	b_1, b_2, b_3, b_4	4	6	4	1			15
a_3	$b_1, b_2, b_3, b_4, b_5, b_6$	6	15	20	15	6	1	63
a_4	b_1, b_2, b_3, b_4	4	6	4	1			15
a_5	b_1, b_2, b_3, b_4, b_5	5	10	10	5	1		31
	Total	24	47	48	27	8	1	155

By supplementing the b-items (basics) with items for cognates, domains, etc., the number of combinations will further increase.

A still further extension will result from applying the same procedure to two, three, and more areas taken at a time. This will lead to sets of notations characteristic of heterogeneous sciences.

If, for instance, we wish to write out notations for heterogeneous sciences made up by combinations of two rows of the above table, say, the four items of row a_2 and the six items of row a_3, we have to take two terms at a time, one from each row, namely,

$$a_2b_1a_3b_1, \quad a_2b_1a_3b_2, \quad a_2b_1a_3b_3,$$
$$a_2b_1a_3b_4, \quad a_2b_1a_3b_5, \quad a_2b_1a_3b_6, \text{ etc.}$$

The total number of such heterogeneous notations is given by the product

$$N = Q \cdot R \cdot S \ldots, \qquad (6)$$

where Q, R, S, etc. represent the number of items in each of the rows.

In the above example one row has six items and the other, four items. Therefore,

$$N = 6 \cdot 4 = 24 \text{ notations.}$$

The great variety and especially the great number of possible combinations of patterns thus obtainable may appear overwhelming at first. However, we have to consider that these notations of knowables will be arranged in zetetic tables similar to a dictionary in which all notations will follow in a systematic order of areas, basics, cognates, etc. convenient for inspection. In fact, in most cases, we will not need exhaustive tables.

RULES FOR FINDING GAPS IN KNOWLEDGE

If we are satisfied to start our search for gaps with small values of n, we can write out in longhand all the possible combinations and arrange them systematically in zetetic tables. For larger values of n, electronic computers can be used for automatic typing of all the combinatorials of dynamic and potential parts of knowledge which form a CDP list.

For the purpose of finding gaps in our knowledge, we thus need: 1) an inventory of all the arts and sciences, 2) a system of notations which will make it possible to operate conveniently with groups of arts and sciences by means of the algebra of combinations, 3) zetetic tables which classify all arts and sciences into convenient groups with their codes written in capital letters, and 4) compiled lists which we call CDP lists (an acronym for "Combinatorial Dynamic and Potential Knowledge"). The latter, when ready, will contain all possible combinations of groups of sciences and their branches written in small letters.

With such auxiliaries at hand, we can find gaps by the following rules:

1) For each of the notations of known sciences or their subdivisions which are listed in the zetetic tables in typed capital letters, we look for a similar notation in the CDP list typed in small letters.

2) Once we have thus identified certain notations of the CDP list as representing known sciences or their known subdivisions, we erase the small letters of each such notation and substitute for them capital letters, writing the corresponding name as it appears in the zetetic table.

3) Whatever notations in the CDP list are left unmarked and unnamed represent gaps in our system of knowledge.

Thus we become aware of the existence of definite gaps. Each such gap indicates, by the absence of a name and by its small-letter notation, the constituent areas, basics, cognates, and other parts from which our search for the unknown has to proceed. Now the process of pathfinding can start. The gaps, if subjected to zetesis, may then be gradually filled by the discovery of new knowledge.

4.14. The Role of Zetetics in the Unification of Knowledge

Knowledge with its divisions and subdivisions may be figuratively compared to an archipelago with a great number of large and small islands dispersed in a sea of ignorance. Is it not ignorance which engulfs the islands of knowledge and hides from our view the basic connective soil--the potential source of new knowledge?

We may extend our simile still further by asking: what is the genesis of those islands? In geological terms, we might refer to volcanic action or to a recession of the sea. But in terms of zetetics, we say that it is the quest for knowledge, stimulated by creato-motive drives and impelled by zetesis, which makes new islands of knowledge emerge from the sea of receding ignorance and raises the old islands to still higher levels. As this process continues, small islands merge with larger ones, so that some day they may even consolidate into continents.

There are three cogent tendencies which lead to the unity of sciences.

a. One tendency is the gradual unification of branches of a particular science to form a more general branch. Developments in the physical sciences during the last hundred years serve as an example of this tendency. Some of its branches such as static electricity, galvanic electricity, and magnetism were united in electrodynamics by the work of Oersted, Faraday, and Ampere. This process of synthesis was extended to include light and heat by the work by Joule, Maxwell, Hertz, J. J. Thomson, and others, so that at present electric phenomena, including radiations, are unified by the electromagnetic wave theory, electronics, and quantum mechanics.

Also significant in this emerging process of synthesis were, first the principle of conservation of matter, then the principle of conservation of energy, and finally the equivalence of mass and energy. These principles, in conjunction with the evolving field theory may some day complete the unification of all branches of physics, including the still unique phenomenon of gravitation. The leading tendency in this process of wider and wider generalizations was based on the assumption that ours is a universe in which all physical phenomena are manifestations of basic principles interconnected with each other and lending themselves to logical-mathematical formulation. It was an assumption instrumental in prompting far-reaching discoveries, modifying our world's views and influencing our ways of life.

b. Another remarkable tendency leading to unity is the formation of border sciences, sometimes called intersciences, like astrophysics and biochemistry. Physical chemistry or chemical physics may serve as an example of how chemistry and physics became linked by electrochemistry, thermochemistry, photochemistry, magnetochemistry, etc. Biology, having been partly unified by the theories of evolution, shows a similar tendency towards unity of its branches. The interscience, biochemistry, shows how it is linked with chemistry. On the other hand, physiological psychology shows its interconnection with psychology. The latter is interconnected with sociology by the emerging interscience of social psychology. With the growth of the intersciences, their borders widen and overlap their mother sciences. They may be regarded as "bridges of knowledge" connecting neighboring insular parts.

c. The third tendency which underlies development toward unity of knowledge we see in the widening scope of research activity. It produces new knowledge, widens our world views, and thus acts as a binding link interlocking knowledge as a whole. Thus, evidence is being collected which shows that the fundamental characteristics of research are identical in all fields of knowledge. The more obvious this development, the more accelerated will become the unifying process.

Since zetetics is mainly concerned with bringing together and systematizing the methods and factors which lead to extension of knowledge in all fields, it may be expected that zetetics as an area of knowledge will lead to more such links.

d. A fourth tendency, still weak but gaining momentum, should also be mentioned. It is the cooperation between valuable aggregations of diversely oriented minds, as we find them in universities. At present they are active singly as researchers in one of the multifarious specialized fields of knowledge. Unfortunately, this extreme specialization, partly due to administrative departmentalization, reduces significantly their unifying influence.

This isolation is produced by the prevailing attitude among specialized scientists and technologists, whose outlook has been restricted by the onesidedness of their particular tasks. Important as those particular fields may be, scientists would profit by following, if only in a general way, the developments in other fields and areas. The need for a wider outlook becomes convincing when we consider how many notable advances are usually made on the frontier lines separating two sciences or on the periphery of two seemingly disconnected areas of knowledge. As example may serve Faraday's discovery of the electrochemical equivalents, which gave rise to electrochemistry, or the Fechner-Weber law, which led to experimental psychology, or Mendel's laws of heredity, which started a new science, genetics, rather belatedly because botanists and zoologists were preoccupied with their particular specialized work.

It is the zetetic approach which opens up new fields, leads to new branches of science, and is destined to unite them with old ones by discovering links towards wider generalizations. The number of such missing links is imposingly large. And the question arises: What is the sequence in which our ignorance, as represented by the gaps, should be attacked? This leads to the next aspect of zetetics, namely problematology.

CHAPTER V

PROBLEMATOLOGY

5. 1. The Subject Matter of Problematology

Problematology is the third subdivision of zetetics. It deals with the origin, systematization, delineation, and selection of research problems. It is also concerned with the automatic preparation of catalogs of such problems by means of computing devices. Problematology serves the intermediate stages of research between the conception of a problem and the general methodological means leading to its solution.

5. 2. Levels of Knowledge and Levels of Problems

Human knowledge evolves from a collection of simple facts, observed by primitive peoples and traditionally transmitted from generation to generation. It tends toward an all-embracing synthesis and may be divided into aggregates for which the word "levels" is appropriate. Knowledge of facts directly observable by the senses in a narrow field of everyday occurrences is on a very low level, as compared with the facts obtained by centuries of research in any of the particular branches of science. A higher level must be assigned to knowledge gained, for instance, as the result of the Copernican system of planetary motion around the sun. A still higher level must be accorded to knowledge gained as a consequence of the theory of evolution of various biological species. To the highest level of knowledge point those systematized facts which are gradually growing into a synthesis of the cosmos, including the totality of life phenomena in all forms.

Problems which arise in the search for such new knowledge can be similarly classified:

Level 1. Problems in connection with tasks for creating new knowledge within a narrow special section of a science.

Level 2. Problems concerned with a larger subdivision (branch) of any particular science.

Level 3. Problems whose solutions may affect a science as a whole, leading to unification of its branches.

Level 4. Problems whose solutions require the knowledge of facts from two or more sciences and which may lead to a system of interrelated principles unifying two or more sciences.

Level 5. Problems whose solutions may affect two or more of the twelve areas enumerated in Section 4. 4, e. g. , the biological and psychological areas.

Level 6. Problems whose solutions may serve as steps to unite the totality of sciences, philosophies, and arts into a universal system of interrelated principles.

5. 3. How Problems Originate and How They are Selected

Any rational choice presupposes the knowledge of entities or things from which a selection has to be made. We may regard this statement as an axiom and extend the word "things" to anything taken from the material, mental, or social sphere. The more complete a given list of things from which we have to make a choice, the more rational the selection we can make. The "things" we are concerned with in our present discussion are "problems in research," problems whose solution may advance knowledge.

In studying the ways in which science and technology develop, challenging questions arise: How do research problems originate? And how are they selected?

Many historians of science find that general trends are discernible in the development of ideas, and that there is a notable logical sequence in the history of discoveries and inventions. If this is so, it is certainly a remarkable phenomenon, considering how rare and isolated the carriers of new ideas used to be. It is claimed that when the time becomes ripe for certain ideas, thinkers with an urge to formulate and to pronounce such ideas appear almost simultaneously, often at widely separated geographical locations. Then a number of active men, scientists, artists, engineers, or scholars, take up these ideas and find ways of carrying them out. It appears highly probable that at each step in the development of human affairs, problems emerge which cannot be regarded as arbitrarily chosen by thinkers just because certain ideas somehow occurred in their minds.

Problems become pertinent as the result of an intellectual and social atmosphere peculiar to the ever-changing pattern of conditions. One of these conditions is determined by the mental and social stresses produced whenever, in a preceding stage, urgent problems were not solved satisfactorily. Another tendency is conditioned by the spirit of adventure, which makes it more interesting to take up exploration of newly discovered territories than to seek new knowledge in partly-developed regions.

This is the reason why sciences and technologies usually develop by sudden extensions of narrow sections of their wide frontiers. Here and there bulges develop, leaving large parts of the old frontiers far behind the new ones. The work of detecting and filling out such lags between disconnected areas is of utmost importance. It is this work which prepares the ground for great generalizations, discoveries, and inventions.

Let us consider, then, the various known methods of selecting such research problems.

1) Individuals do what they feel inspired to do.
2) Individuals choose to do what they feel capable of doing.
3) Groups at various universities take up what appear to be the most promising problems in the most fertile fields.

4) Groups at existing research centers choose programs suitable for the manpower and equipment they have at their disposal or can muster.
5) Tasks are selected strictly for definite defense purposes, or for economic advantages, or in line with governmental policies.

Each of these methods has its merits. Each has contributed to the advancement of science and technology. It can be argued, however, that in all of them the choice of problems is based on the subjective judgments of an individual or on the opinions of a small group.

It is often contended that the most reliable guide in the selection, as in the solution of problems, is a mysterious agent active in the mind of a researcher which allegedly makes his thought leap in the right direction. However, these leaps (sometimes called frog leaps) often prove to be just haphazard jumping from one possibility to another, without any guide whatsoever, and in most cases end in frustration.

Defense of this "method," if it deserves the name, is based exclusively on cases in which successful selection of problems and their solution has been achieved by researchers who could not remember the circumstances and the steps which led them to make their choice. Searching intensively for answers to intriguing questions constitutes a state of mind unfavorable for tracing consciously the ways of thinking. Attention is then concentrated on those questions to such a degree that it can hardly be focused on introspection. The researcher is, thus, unaware of the process which led to his choice. Of the many alternatives which his mind probed unconsciously, the one he finally chose was imprinted on his memory, while the others cannot be recalled. Hence the impression of a successful leap.

The question next arises whether a method of selecting problems can be devised, which, compared with those enemerated above, would be more objective, complete in its coverage, and adaptable to the increasing number of workers engaged in research. Since 1926 efforts have been in progress toward solving this particular problem from the point of view of zetetics. Some early results, in connection with the investigation of dielectrics, were published in 1931.* An outcome of further development consists of a number of rules based on a simple application of the combinatorial algebra, as already discussed in the previous chapter.

At this point, however, a few remarks of a psychological character may serve as an introduction to the enumeration of the rules for selection of problems.

5.4. Processes Involved in the Formulation of Problems

Whenever we are confronted with a problem--a situation characteristic of research activity in all fields of science and technology as well as in artistic creation--we are puzzled by some missing link or links in the flow of our ideas and experience. We wonder then which direction our thinking should take; usually a feeling of elated inquisitiveness, often mixed with oppressive awareness of ignorance, drives our thought in attempts to solve the difficulty.

We react, first, by having recourse to personal sources of information, our memories and available literature; second, by trying to reduce the problem to a brief and concise form or possibly to a visual image by means of which we can easily think about the problem as a whole. It may assume the form of a written note, which may be further reduced to a single sentence and finally may even be contracted to what can be the title of an investigation. The few words of a well-formulated title usually represent the main concepts and phenomena around which the problem centers. Such a preliminary formulation, extended in a logical way, may thus prepare the way to a solution.

Seldom will the road be a direct one. Usually, our thoughts zig-zag from one approach to another until imagination, aided by a bright idea or inspiration, takes us from a winding trail to the main road. The process of mental activity which follows the event of "coming across a problem" shows only one of the means by which problems originate in our minds, and how we can put them into a concise form.

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* J. T. Tykociner and E. B. Paine, "Classification of Research Problems on Dielectrics." Trans. Ill. State Acad. of Science, Vol. 24, No. 2, Dec. 1931, pp. 300-309.

Another process, based on ideas exposed in the publication of 1931 mentioned above, consists of "generating problems" by starting from a number of known entities connected with a branch of science. One then groups the entities into categories, and, finally, sets up schemes called outlines for generating combinations of one entity from each category so that each combination produces a problem title. The totality of all such combinations then represents a series of interconnected problems.*

Of the series thus formulated, some may be of immediate interest, others may become the object of future investigations, and some may have been solved already.

By composing such lists of problems, we gain a general view of a particular field of knowledge. The only factor which prevents a list from becoming complete is the limited number of the original entities (items ordered in categories) that we can include in the scheme. The limits depend on practical considerations as well as on scarcity of knowledge in a particular field.

In setting up outlines for generating and cataloging research problems, indexes of books, especially monographs which contain comprehensive reviews of an entire section or branch of science, may serve as useful guides or sources of entities and terms. These indexes can be supplemented with cross indexes published periodically by abstracting journals in specialized fields, for instance, in chemistry, physics, electrical engineering, mathematics, psychology, and so on. In preparing our schemes for particular sciences, a review of pertinent parameter groups arranged in matrices proved of value.

Later on, examples will be given from three branches of research to illustrate schemes for listing problems from the point of view of methods, concepts, parameters, and phenomena.

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* Later, F. Zwicky applied a similar idea in developing telescopes and jet engines. See Observatory, Vol. 68, No. 121 (1948) and Helvetica Physica Acta, 21, 299 (1948).

5.5. General Scheme and Outline for the Generation and Selection of Problems

A simplified way of representing the basis for a systematized selection of problems is shown in Figure 5.1. Suppose, for the sake of simplicity, that we are interested in extending a certain region of knowledge having three categories of characteristics peculiar to that branch of science, and that only two research methods are available or can be applied in the investigation.

Imagine as an illustration that we have a filing cabinet with drawers, each one for storing information in connection with a definite problem. To identify the drawers, those along the axis of the first category are marked a and b; those of the second category are marked A, B, C, D; and those of the third category are marked 1, 2, 3. Thus the drawer marked with a circle would be labeled 2 B a; the drawer marked with a square gets a label 1 C b; similarly each of the other drawers can be annotated to indicate a particular problem. If m, n, and p represent the number of drawers along each of the axes, the total number of problems, N, will be equal to the total number of drawers.

$$N = m \cdot n \cdot p = 2 \cdot 4 \cdot 3 = 24 \text{ problems}$$

Let us apply the above generalized scheme to a concrete example--for instance, to the study of interrelations of electric and thermo properties of certain substances. An outline for generating and cataloging related research problems will look in this case as follows:

Category I. Methods of research or approaches
a. Experimental b. Theoretical $m = 2$

Category II. Properties to be studied
A. Heat Conductivity B. Electric Conductivity $n = 4$
C. Specific Heat D. Magnetic Susceptibility

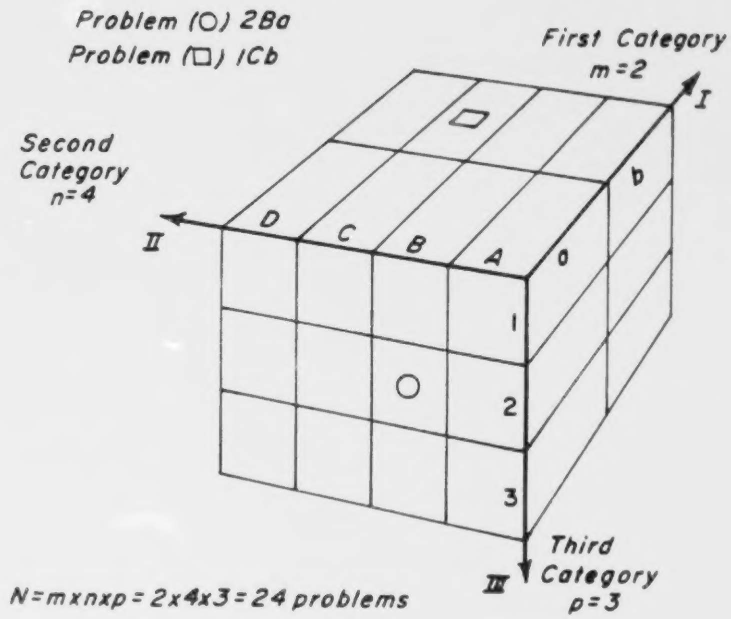
Problem (○) 2Ba
Problem (□) 1Cb
First Category
m=2
I
Second
Category
n=4
II
D
C
B
A
a
b
1
2
3
Third
Category
p=3
III
N=mxnxp=2x4x3=24 problems

FIGURE 5. 1. SYSTEMATIZATION AND SELECTION OF PROBLEMS

Category III. Physical states to be investigated

1. Gas 2. Liquid 3. Solid p = 3

According to our outline, the total number of problems is N = m· n· p, which equals 2·4·3 = 24 problems. Among others the following titles for investigation may be derived:

for Problem 2Ba

"Experimental Study (a) of Electrical Conductivity (B) of Liquids (2)"

for Problem 1Cb

"Theoretical Study (b) of Specific Heat (C) of Gases (1)."

By referring to Figure 5. 1 and the above example, we can now present a general scheme helpful in preparing specific outlines for enumerating and selecting research problems.

Category	Items	Symbols	Number of items
I.	Items specify steps in research methods.	a, b, c, d, . . .	m
II.	Items specify a particular group of characteristics, phenomena, or concepts peculiar to the chosen branch of science.	A, B, C, D, . . .	n
III.	Items specify another group of characteristics, phenomena, or concepts peculiar to the chosen branch of science.	1, 2, 3, 4, . . .	p
IV.	Still another	$\underline{a}, \underline{b}, \underline{c}, \underline{d}, \dots$	q
.	. . . .	. . . .	.
.	. . . .	. . . .	.

Such a scheme for an outline, as shown above, is tabulated in four columns and a number of rows. The first column enumerates the categories (I, II, III, IV, etc.); the second column lists specific items for each category; the third indicates the symbols used to identify items in each category; and the fourth column shows the symbols for the number of items in each category. The first row with its symbols a, b, c, d, . . . specifies steps of the general research methods which are adaptable to this particular science. All the other rows with their respective symbols specify sets of homogeneous items or entities united by some common characteristic.

5.6. Rules for Generation, Systematization, and Selection of Problems

The main rules for systematic generation of problems are as follows:

1) Prepare an outline according to the general scheme tabulated above by dividing a particular section of a branch of science

which we wish to investigate into categories of entities and its items.

2) Compile a complete list of notations to represent pertinent "problems" obtained by a combination of one and only one item taken from each category, so that each such combination consists of one small letter, one numeral, a small letter marked by a bar and so on. For instance one would have problem 2Bd$\underline{a}$ and problem 4Ac$\underline{c}$.

3) Check the total number, N, of all such combinations by forming the product

$$N = m \cdot n \cdot p \cdot q \;\ldots.$$

The larger the number of categories and the larger the number of items in each category, the greater will become the total number of problems.

4) Transform each of the combinations of symbols into words and obtain thus a catalog of briefly defined problems for each section, branch, science, or combination of sciences and technologies.

5) Mark in the catalog those problems for which all the immediately needed or desired information is available. The remaining problems will represent gaps in our knowledge to be filled by research.

6) Establish a logical sequence for the remaining problems. This should be such that the simple ones can be started ahead of all others and that each consecutive one supplies useful information for attacking the next. Each problem, therefore, must be reviewed and analyzed in order to define it more completely, and to determine the chances of solving it with available scientific means, or to consider new means of attacking the problem.

7) Should a set of problems prove to be equivalent from the point of view of logical sequence, preference is given to those which may be helpful in solving pertinent problems of other sciences. As many as possible of this kind of problem can be attacked simultaneously, whenever sufficient means (manpower, space, equipment, and materials) are available.

8) If for any reason such logically equivalent problems cannot be tackled simultaneously, then a choice will be made in terms of the education, experience, interests, and insight of the investigator.
9) Each advance made in the automatic methods of simultaneously observing, measuring, recording, or analyzing various systematized data can then be used for unifying a series of related problems into a single group. Thus, the total number of projects to be set up may be reduced considerably.
10) Appropriate additions must be made to the categories whenever a new theory predicts the existence of as yet unknown phenomena, properties, entities, or constants whose discovery or experimental determination requires investigation.
11) Whenever a significant advancement increases our knowledge by a discovery of a new phenomenon, process, or factor, new items must be added to one or more of the rows of categories. Similarly, new categories and items will need to be added whenever a discovery opens up an entirely new field requiring investigation, or discloses a new theoretical approach, or leads to new means of exploration.
12) As a consequence of Rules 10 and 11, periodic preparation of revised lists will be required, which will systematically extend the range of problems calling for solution and eliminate those already solved.
13) If the number of categories becomes too large for handling, and titles too lengthy or bulky, recourse must be taken to dividing categories and their items into sections, each to include some of the main entities which may unite the separate sections.

With minor modifications the above set of rules also applies in cases when the scope of the investigation includes two or more sciences involving various areas.

Not all the problems in any list have to be investigated. The generalizations obtained by the solution of an important problem may reduce many others to obvious special cases whose solutions then become predictable. On the other hand, every fresh generalization produces new problems which consist in the verification of predicted new facts, relations, and phenomena. This is why catalogs need to be revised periodically. Every edition thus shows the problems which existed just before publication of that particular catalog.

5.7. Example Taken From the Field of Dielectrics

The first example refers to a research project carried out in 1926 and 1927. The project was related to problems of dielectrics as applied to the deterioration of high-voltage electric power cables. It was then that the idea of systematization and selection of problems was conceived and applied for the first time.

The entire problem was divided into five classes, for each of which an outline was prepared. Given below is the outline of problems for Class IV, quoted in the paper on "Classification of Research Problems on Dielectrics" by Tykociner and Paine.[*]

Problems in deterioration of insulation are directly connected with physical properties of dielectrics and aim principally at the discovery of correlations which may exist between the following three distinct groups of physical factors, each representing a category:

factors connected with the distribution of different forms of energy in a dielectric

A. Dielectric constant
B. Conductivity
C. Ionization
D. Electrostriction
E. Dielectric absorption
F. Dielectric losses
G. Dielectric strength

factors determining the structure of a dielectric

1. Vacuum
2. Gases
3. Liquids
4. Crystals
5. Amorphous materials
6. Laminated materials
7. Textile materials

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[*] See footnote in Section 5.3.

agencies which influence the dielectric

a. Intensity of applied potential
b. Duration of applied potential
c. Wave form of applied potential
d. Frequency of applied potential
e. Action of magnetic flux
f. Action of thermal agitation
g. Action of radiations
h. Mechanical action

By including the functional characteristics of research (a, b, c, d) we can assemble the above groups of notations as follows:

IV.
A B C D E F G
1 2 3 4 5 6 7
a b c d e f g h
a b c d

and obtain by combination N = 1 · 7 · 7 · 8 · 4 = 1568 problems.

For instance, IVE3*d*c denotes a problem "Measurement of the Influence of Frequency on the Dielectric Absorption of Liquids." The problem denoted by IVG2*g*d may serve as another example. It signifies "Theory of the Action of Ultraviolet Radiations on the Dielectric Strength of Gases."

A simplified diagrammatic picture of this field of problems is shown in Figure 5. 2. However, here one of the categories had to be disregarded in order to comply with the limitations of the three dimensional diagram. So,

1) category one on the x-axis is assigned to properties which are connected with the distribution of various forms of energy in a dielectric. Six items have been chosen for convenience, but others could of course be added.
2) category two on the y-axis is assigned to factors determining the structure of a dielectric. Again, six entries have been used arbitrarily.
3) category three on the z-axis is assigned to research methods--three items in this case.

The total number is accordingly reduced to

N = 6 · 6 · 3 = 108 problems.

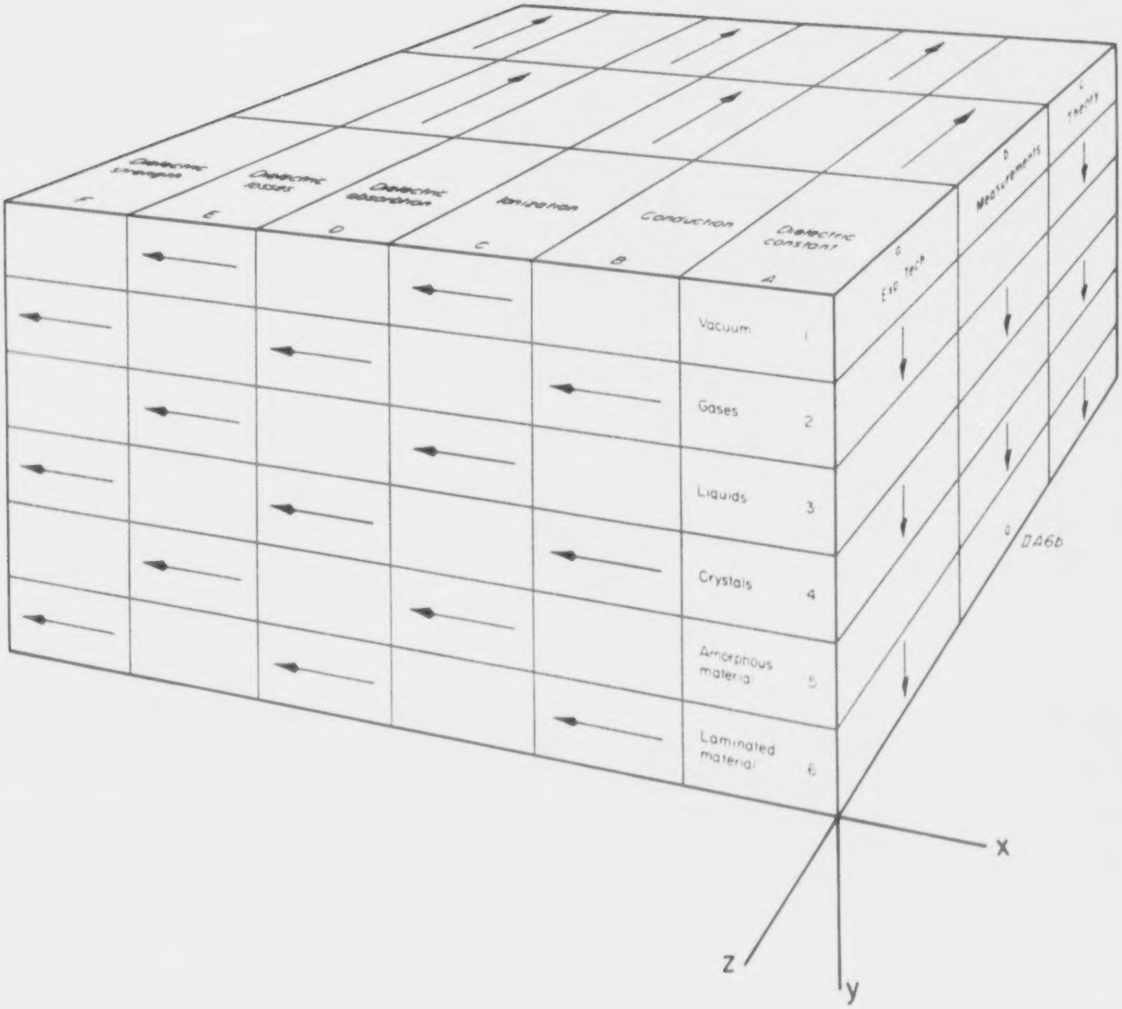
Dielectric strength
F
Dielectric losses
E
Dielectric absorption
D
Ionization
C
Conduction
B
Dielectric constant
A
a
Exp Tech
b
Measurements
c
Theory
Vacuum 1
Gases 2
Liquids 3
Crystals 4
Amorphous material 5
Laminated material 6
DA6b
X
Z
y

FIGURE 5. 2. PROBLEMS IN PROPERTIES OF DIELECTRICS

BEST COPY AVAILABLE

So, for instance, the problem marked with a circle, II A 6 b, pertains to "Quantitative Investigation of Dielectric Constant in Laminated Materials."*

Further examples of the application of the described method for selecting problems in various fields of science and technology will be given in the following discussion, which deals with the preparation of catalogs of problems.

5.8. Preparation of a Catalog of Problems

GENERAL CONSIDERATIONS

A rational selection of problems in any field of research presupposes the existence of as complete a list of tasks as it is possible to prepare on the basis of established knowledge. Worth considering in this connection are facts and phenomena as yet undiscovered, but whose existence is rendered probable on theoretical grounds. In order to prepare such a list, it is not sufficient to be acquainted with the subject matter of only one branch of science even though it appears to include all the aspects of the problem. Usually, problems arise on the very borderlines of a few sciences and sometimes they give rise to new branches of science. Therefore, a wide scientific outlook and insight, but not necessarily expertness, is required in setting up an outline as an initial step in preparing a catalog of problems for research.

As shown in our first example, an outline consists of a large number of items related to the particular field of knowledge, so chosen that nothing essential is omitted. The items are classified into categories by assigning to each of them a characteristic symbol. The next step consists in the routine work of making up such combinations of symbols that each combination includes one and only one item from each category. Finally, each combination thus derived is translated into words, so that we obtain a logically consistent title for each problem.

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* It should be noted that the examples in dielectrics, quoted above, refer to the state of knowledge as it existed about 30 years ago. Meanwhile, great progress has been made both in the theoretical and experimental knowledge of dielectrics. Many of the problems have been tackled and solved, others have been reduced to special cases with results predictable on the basis of generalizations.

The last two steps represent time-consuming tasks if performed by longhand or manual typing. The question of how to do such operations electronically had to be considered.

The immediate availability of the ILLIAC high-speed electronic digital computer was tempting. Thanks to the co-operation of Dr. R. E. Meagher, in charge of the Digital Computer Laboratory, and of Mrs. J. Blankfield, who undertook the programming, the first examples of lists of problems were obtained by the use of the ILLIAC in November, 1956.*

In preparing the first three catalogs, no attempt was made to obtain exhaustive lists of problems. Rather, the number of titles to be printed was reduced for the sake of economizing ILLIAC's valuable time. The only purpose was to test this new application of the electronic method and to get experience in preparing the outlines and in programming the ILLIAC for this particular task.

First, outlines of the following three groups of research problems from different branches of science were prepared:

1. Radiation Patterns of Antennas,
2. Study of Structure of Electrically Produced Striations in Gases Enclosed in Tubes, and
3. Sociology of Population.

On the basis of these outlines the programming was done, and three perforated tapes were produced for controlling the ILLIAC and operating the teletype printing machine. They were

1. the master program tape,
2. the input tape, and
3. the output tape.

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* Procedures and data on programming the ILLIAC were described by Mrs. Blankfield. See Appendix One of Research as a Science--Zetetics (1959 ed.)

The master program tape serves for any catalog containing no more than seven categories. However, each particular catalog requires its special input and output tapes.

CATALOGS OBTAINED WITH THE AID OF THE ILLIAC

The outlines for three catalogs of problems obtained by using the ILLIAC are given in Tables 5. 1, 5. 2, and 5. 3.

Table 5. 1 refers to research on "Radiation Patterns of Antennas." It shows 15 selected items classified into five categories. The total number of titles of problems obtained with the ILLIAC amounts to N = 216.

A sample page of this catalog is reprinted in Table 5. 4. It shows, among others, the title of problem No. 90; "Measurements of Theta Polarization Patterns of Two Spiral Antenna(s) at Microwave Frequencies."

TABLE 5. 1
OUTLINE OF PROBLEMS FOR RESEARCH
ON RADIATION PATTERNS OF ANTENNAS

	Categories	Items	Number of Items
I.	Methods of Research:	Theory Measurements Discrepancies	3
II.	Type of Polarization:	Theta Phi	2
III.	Number of Antennas in Array:	One Two Three	3
IV.	Type of Antenna:	Dipole Spiral Antenna Slotted Waveguide Folded Waveguide	4
V.	Frequency Range:	VHF (Very High Frequency) UHF (Ultra High Frequency) Microwave	3

Total Number N = 3 x 2 x 3 x 4 x 3 = 216 Problems

Another example of a catalog of problems obtained by the use of the ILLIAC refers to a research program which was carried out by the author in Dr. L. Goldstein's Gaseous Electronics Laboratory.

Table 5. 2 refers to this "Study of Structure of Electrically Produced Striations in Gases Enclosed in Tubes." It shows 15 selected items classified into four categories. The total number of titles of problems obtained with the ILLIAC amounts to N = 144.

For instance, the title for problem No. 55 reads "The Effect of Gas Pressure on the Structure of Striations in Helium at DC Potential as Dependent on Tube Diameter." A sample page of this catalog is reprinted as Table 5. 5.

TABLE 5. 2
OUTLINE OF PROBLEMS FOR THE STUDY OF STRUCTURE OF ELECTRICALLY PRODUCED STRIATIONS IN GASES ENCLOSED IN TUBES

Categories	Items	Number of items
I. Physical Conditions:	Temperature Gas Pressure Magnetic Field Current Density	4
II. Nature of Gas:	Molecular Hydrogen Helium	2
III. Frequency of Applied Potential:	DC, Zero Audio Radio VHF UHF Microwave	6
IV. Geometry of Tubes:	Diameter Length Position of Electrodes	3

Total Number N = 4 x 2 x 6 x 3 = 144 Problems

Finally, the third example of cataloging problems for research was purposely chosen from an entirely different domain, far removed from problems of physics and electrical engineering, namely, from sociology. Hence, Table 5. 3 refers to problems related to "Sociology of Population." It shows 14 selected items classified into 5 categories. The total number of titles of problems obtained with the ILLIAC is N = 162.

For instance, the title for problem number 24 reads "Historical Study of Migration in the U. S. as Affected by Form of Government[*] and Economic Status." The title for problem number 104 reads as follows: "Statistical Study of Fertility in the U. K.[**] as Affected by Density of Population and Educational Level." A sample page of this catalog enumerating problems 34 to 45 is reprinted as Table 5. 6.

TABLE 5. 3
OUTLINE OF PROBLEMS RELATED TO SOCIOLOGY OF POPULATION

Categories	Items	Number of Items
I. Methods:	Historical	
	Statistical	
	Descriptive	3
II. Social Conditions:	Crime	
	Migration	
	Fertility	3
III. Regions:	U. S.	
	U. K.[**]	
	Canada	3
IV. Social Structure:	Density of Population	
	Form of Government[*]	2
V. Personal Conditions:	Health	
	Educational Level	
	Economic Status	3

Total Number N = 3 x 3 x 3 x 2 x 3 = 162 Problems

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[*] It would have been better to formulate this item as "Governmental Policies."

[**] U. K. is an abbreviation for the United Kingdoms.

TABLE 5.4
SAMPLE PAGE FROM A CATALOG OF PROBLEMS RELATED TO RADIATION PATTERNS OF ANTENNAS

82 Measurements of Theta Polarization Patterns of a Single Folded Waveguide(s) at VHF

83 Measurements of Theta Polarization Patterns of a Single Folded Waveguide(s) at UHF

84 Measurements of Theta Polarization Patterns of a Single Folded Waveguide(s) at Microwave Frequencies

85 Measurements of Theta Polarization Patterns of Two Dipole(s) at VHF

86 Measurements of Theta Polarization Patterns of Two Dipole(s) at UHF

87 Measurements of Theta Polarization Patterns of Two Dipole(s) at Microwave Frequencies

88 Measurements of Theta Polarization Patterns of Two Spiral Antenna(s) at VHF

89 Measurements of Theta Polarization Patterns of Two Spiral Antenna(s) at UHF

90 Measurements of Theta Polarization Patterns of Two Spiral Antenna(s) at Microwave Frequencies

91 Measurements of Theta Polarization Patterns of Two Slotted Waveguide(s) at VHF

92 Measurements of Theta Polarization Patterns of Two Slotted Waveguide(s) at UHF

93 Measurements of Theta Polarization Patterns of Two Slotted Waveguide(s) at Microwave Frequencies

TABLE 5. 5
SAMPLE PAGE FROM A CATALOG OF PROBLEMS FOR THE STUDY OF STRUCTURE OF ELECTRICALLY PRODUCED STRIATIONS IN GASES ENCLOSED IN TUBES

52 The Effect of Gas Pressure on the Structure of Striations in Molecular Hydrogen at Microwave Potential as Dependent on Tube Diameter

53 The Effect of Gas Pressure on the Structure of Striations in Molecular Hydrogen at Microwave Potential as Dependent on Tube Length

54 The Effect of Gas Pressure on the Structure of Striations in Molecular Hydrogen at Microwave Potential as Dependent on Position of Electrodes

55 The Effect of Gas Pressure on the Structure of Striations in Helium at DC Potential as Dependent on Tube Diameter

56 The Effect of Gas Pressure on the Structure of Striations in Helium at DC Potential as Dependent on Tube Length

57 The Effect of Gas Pressure on the Structure of Striations in Helium at DC Potential as Dependent on Position of Electrodes

58 The Effect of Gas Pressure on the Structure of Striations in Helium at Audio Potential as Dependent on Tube Diameter

59 The Effect of Gas Pressure on the Structure of Striations in Helium at Audio Potential as Dependent on Tube Length

60 The Effect of Gas Pressure on the Structure of Striations in Helium at Audio Potential as Dependent on Position of Electrodes

TABLE 5.6
SAMPLE PAGE FROM A CATALOG OF PROBLEMS RELATED TO SOCIOLOGY OF POPULATION

34 Historical Study of Migration in the U. K. as Affected by Form of Government and Health

35 Historical Study of Migration in the U. K. as Affected by Form of Government and Educational Level

36 Historical Study of Migration in the U. K. as Affected by Form of Government and Economic Status

37 Historical Study of Fertility in the U. S. as Affected by Density of Population and Health

38 Historical Study of Fertility in the U. S. as Affected by Density of Population and Educational Level

39 Historical Study of Fertility in the U. S. as Affected by Density of Population and Economic Status

40 Historical Study of Fertility in the U. S. as Affected by Form of Government and Health

41 Historical Study of Fertility in the U. S. as Affected by Form of Government and Educational Level

42 Historical Study of Fertility in the U. S. as Affected by Form of Government and Economic Status

43 Historical Study of Fertility in Canada as Affected by Density of Population and Health

44 Historical Study of Fertility in Canada as Affected by Density of Population and Educational Level

45 Historical Study of Fertility in Canada as Affected by Density of Population and Economic Status

CATALOG OBTAINED WITH THE AID OF IBM EQUIPMENT

Originally it was planned to use standard IBM equipment for automatic printing of card catalogs, each card bearing the title of one problem instead of having all titles printed on a continuous sheet. However, such a task proved to be more complicated than expected.

Nevertheless, it was necessary to obtain a concrete example to prove the possibility of using IBM equipment for automatic printing of continuous-sheet catalogs on the basis of outlines of categories and items similar to those used with the ILLIAC.

Thanks to the cooperation of G. R. Beam and B. J. Meagor of the University's Statistical Service Unit, this task has been successfully performed. The same outline was used for problems related to "Sociology of Population" as prepared for the ILLIAC and shown in Table 5. 3.*

5. 9. The New Zetetic Function

In the electronic computing devices such as the ILLIAC and IBM, we possess the machinery for producing catalogs of problems for a vast range of interrelated fields of research. These new aids will be significant in approaching research as a social activity through a continuously conducted systematization, selection, and formulation of problems. Starting in each branch of science and technology from a narrow range of problems ready for immediate attack, this activity should be gradually extended to a wider and wider range of problems relating two and more sciences. Each of these steps will lead to means of tackling still more general problems. Inversely, every extension in the direction of generalization will facilitate the formulation of particular tasks in narrower specialized fields.

The storing of recorded knowledge in libraries, archives, and museums and making this knowledge available to researchers is related to past achievements; in the same way the new function is related to planning future accomplishments in the extension of knowledge. It will supply an over-all glimpse of the border-lines of knowledge and will indicate those gaps in our knowledge which require foremost attention by those dedicated to research.

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* See Appendix Two of Research as a Science - Zetetics by J. T. Tykociner (1959 ed.).

At this point the question suggests itself as to who or what institution should take up and develop this new function. Of the many solutions possible, the simplest appears to be as follows. To begin with, let individual research workers or a team of investigators take up the function of cataloging problems from the field with which they are directly concerned. Then universities and other research organizations having more general goals will form centers for cataloging and systematic ordering of problems covering a much wider range. Similar activities on a still broader scale, embracing all arts, sciences, and their branches, may be taken up by the National Research Council and National Science Foundation.

Libraries connected with universities and research institutes could take up the task of preparing catalogs of problems. However, personnel acquainted with the processes of research in a variety of scientific fields would have to be employed in order to cope with preparing and coding the outlines; also some personnel would have to prepare codes and operate electronic devices designed for automatic selection of bibliographies.*

Another solution may consist in setting up a special Institute of Zetetics, whose function would be to carry out continuous cataloging as well as establishing a rational sequence for taking up the solution of problems as suggested by rules 1 to 13. It need hardly be mentioned that the only purpose of such an institute would be to supply means of orientation rather than to impose its findings upon researchers or research centers. Free creative activities of researchers would thus be stimulated.

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* Ralph R. Shaw. "Machines and the Bibliographical Problems of the Twentieth Century," Bibliography in an Age of Science. Urbana, Illinois: University of Illinois Press, 1951. Page 58.

5.10. Concluding Remarks

The described method of generation, systematization, and selection of problems includes both an analytic and a synthetic approach. It consists in resolving research problems into their component parts and in building up mental outlooks for the following purposes:

1) To obtain perspective of an entire field.
2) To find interrelations between various parts of knowledge.
3) To detect gaps in knowledge.
4) To establish a rational sequence of problems.
5) To make possible selection of problems from the point of view of aims and available talent.
6) To show to the investigator lost in the details of his labors the channels uniting his particular task with other, wider problems.
7) To set up comprehensive general plans of attack on problems vital to human existence.

While the function of storing and making knowledge available to researchers is very well established and growing in effectiveness, the function of systematization, selection, and formulation of problems is still evolving from its first stages of development. Both functions are essential and equally important in research activity. Therefore, it should be expected that every improvement in methods of systematization and selection of problems will accelerate the advancement of science and technology.

CHAPTER VI
ZETESIS

6. 1. Zetesis as an Activity

In this chapter we are concerned with the question: How does the human mind proceed in the activity of increasing mankind's most precious possession, systematized knowledge? We called the activity by which it proceeds zetesis, meaning activity of investigation in both research and artistic creation. It may be briefly described as follows:

> Zetesis is that activity which converts the unknown into the known and transforms our present state of knowledge into a more precise, a more expanded, and a more unified state. It may be looked upon as a process whereby knowledge and experience are made to grow into an ever-developing, interrelated system. In a wider sense this process is also instrumental in creating works of art.

Zetesis is a complex activity. In order to get an insight into its operation, we may consider it as consisting of four functionally interconnected parts:

1) The initiating impulse,
2) The utilization of available cultural resources,
3) The imaginative creato-motive drive, and
4) The logical operation.

It is the creato-motive part which again and again intensifies the impulse, stimulates the logical operation, makes effective use of available knowledge, suggests new techniques, and thus sustains activity in a circuitry of mental processes. There is no reason to assume that this process of generating cultural additions is different for any of the areas of knowledge. It is the relative participation of the four ingredients that changes from field to field. So, for instance, in aesthetic creation the imaginative ingredient predominates, while in research logical operations play a more important role.

In order to illustrate the general character of zetesis, let us suppose that researchers in different fields observe the same visible phenomenon, for instance, the phenomenon implied by the word "fire." Fire and flames may be studied from many different points of view. The anthropologist collects data regarding the role fire has played in the life of primitive peoples. The student of comparative religion is interested in its mythological content and the significance of fire in ancient forms of worship. The demographer investigates the effect that the knowledge of fire-making had on the migration of people from hot to cooler geographical regions. The sociologist studies the behavior and the reactions of people to each other when they are sitting around a bonfire or gathered at a conflagration. The psychologist watches the reactions of various individuals to the cry, "Fire, fire!" The chemist analyzes the material consumed and the resulting ashes and gases produced by combustion. The physicist investigates the light and heat radiated by flames. The mineralogist or the geologist searches for combustible materials which will sustain fire. The navigator looks at it as a direction finder and a means of communication. The economist considers its industrial advantages and the losses caused by fires. The engineer is eager to find means for controlling flames for the purposes of producing steam, melting metals, or moving vehicles. The artistically inclined painter is impressed by the colors, shapes, motions, and shadows produced by the flickering flame. Finally, a musically endowed observer may be fascinated by the interplay of gay cracklings or ominous murmurs which suggest motives for composition.

Each one of these fourteen researchers chooses as his subject matter a particular aspect of the same phenomenon. Each makes his choice in accordance with his particular ability and inclination. Each follows his own quest for knowledge.

Diverse as were their fields of interest, each researcher had to start by formulating his problem. He had to select pertinent sets of data, organize them, and find means for obtaining answers to the numerous questions encountered at every step on his way toward the solution of his problem. Often the results thus obtained were illusive or inconsistent. In such cases, they had to be checked by searching for new data which confirmed previous assumptions; or else the problem had to be reformulated, recourse taken to fresh insight, new concepts invented on the basis of a new set of assumptions, new techniques found for obtaining still more pertinent facts, and the process of searching repeated. Finally, by moving along this tortuous path, some of the many inconsistencies and doubts disappeared. In the above example, individual researchers working independently in various fields took up the study of a definite phenomenon; each was interested in a different aspect of the same subject matter. However, during the last twenty-five years, as vast fields of knowledge have been opened for investigation, it has become necessary for individual researchers to join forces in attacking the problems which are growing in number and mounting in complexity. Nowadays scientists and engineers find that groups of individuals with a diversity of talents are more effective and that they accelerate the production of new knowledge.

Such groups are not confined to local laboratories or to any one organization. Not even national boundaries prevent them from unifying their efforts to enrich our store of knowledge. For instance, the discovery of a new element, Nobelium, as described in Physics Today, is characteristic of what can be done by scientists joining forces.* Nobelium, element number 102, was discovered in March, 1957, by a joint international research team in the course of experiments conducted at the Nobel Institute for Physics in Stockholm. Announcement of this event was made simultaneously on July 9th in Sweden, Great Britain, and the United States. The group responsible for the success of the experiment included physicists and chemists from the Argonne National Laboratories (U. S.), the Atomic Energy Research Establishment at Harwell (Britain), and the Nobel Institute (Sweden) Argonne provided the needed amount of curium which was shipped to Harwell where the targets were prepared; Harwell provided the rare carbon isotope C_{13} used to provide the bombarding particle; and the Nobel Institute provided the cyclotron, some special equipment, and a staff of physicists, chemists, and technicians.

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* August, 1957, p. 36.

Another striking example of such cooperation is the so-called International Geophysical Year (1957-58). During that period five thousand scientists from fifty-five nations agreed to work on a joint program of geophysical studies embracing our entire globe, its atmosphere, and its ionosphere. This grandiose team, organized on a scale never before attempted and working for more than a year, has furnished knowledge that would otherwise have taken about twenty years to collect and systematize.

Thus zetesis, which has been carried on for ages mostly by lone, individual researchers, has grown during the last half century into a coordinated group activity and recently is assuming the form of a cooperative enterprise on a national and an international scale.

6. 2. Preliminary Stages of Zetesis

THE SPECULATIVE STAGE

Let us consider an individual researcher (or a team of them) and analyze the steps of his activity. His purpose is to find an answer to one or a set of questions which occupy his mind. He feels uneasy because of his ignorance, challenged by his pride, and driven by his inquisitiveness until in his search he finds at least a trail which may lead him to the desired aim--the solution to what puzzles him or what is called a "problem."

This is the first or the speculative stage. At this stage, the problem is not yet completely formulated. It appears in one's mind when stimulated by curiosity which may be induced, for instance, by watching the course of a phenemenon, by unexpected results of an experiment, by a puzzling logical inconsistency, or even by a dream. The mind is playing with ideas based on material supplied by impressions, memory, and imagination. At this stage, the approach can be regarded as a kaleidoscopic way of forming mental patterns from various angles of reflection.

Having found a trail, the hazy conglomeration of previous knowledge crystallizes in the researcher's mind as a clear definition of his problem. It is now ready to be written down with all the main features briefly, but precisely, described. If the problem is a complex one, he will break it up into a number of interrelated parts, each of which he can tackle more conveniently.

Next, the question will occur to him: Has anyone else worked on this problem? Perhaps it has been solved already. Our investigator will search the available literature and make all possible inquiries in order to obtain a bibliography as complete as his patience and time will allow. To write a monograph on the development of the problem would be useful in a case of great significance.

Very seldom will he find that his is a virgin field, never touched by others. But seldom will he come to the conclusion that his problem has been fully solved and is already included as a part of some science.

If at this crossroads he is still interested, he will be faced with the necessity of making a decision. How should he approach the problem so that his research will best contribute to the enlargement of the body of knowledge already established? In other words, he will have to plan and take into consideration the past historical developments pertinent to his work.

UTILIZATION OF AVAILABLE CULTURAL RESOURCES

Utilization of inherited cultural resources is one of the functions of research in all areas of human development. As Newton said in giving credit to his predecessors: "If I have seen a little farther than others, it is because I have stood on the shoulders of giants."

The influence of cultural resources is clearly shown in the following excerpt from a lecture by George Sarton, the distinguished historian of science.

> How does the continuity of scientific efforts manifest itself? Every chapter in the history of science is an illustration of it. It is true great discoveries are discontinuities, but when one analyzes them one realizes that these discontinuities are more apparent than real. The function of great men is essentially synthetic: they put together elements borrowed from everywhere and complete the building prepared by many others. This is not a disparagement: without them the building would not exist, but even they could not have built it if most of the materials had not been handy. . . And the same is true of the whole past. Each man adds his stone to the building, and sometimes an old building is broken to pieces and the old stones are used again sooner or later for a new one. Each man continues the work of his fellows--seen or unseen, known or unknown, friends or enemies; each people continues the task of the people who preceded them, and so on. The continuity is hardly if ever broken, because the materials of science are not sufficiently tangible to be capable of destruction, and because the cooperation of all men in this their supreme duty is spontaneous. They cooperate not because they want to, but rather because it is their function and destiny to do so. Neither race nor faith nor political boundaries can be an obstacle to a collaboration which involves the whole of mankind. *

The necessity of acquiring knowledge of the literature pertinent to a particular problem has already been mentioned. However, the problem in question is often indirectly connected with problems in other fields, even in entirely different areas of knowledge. In such cases the cooperation of two or more scientists from different fields is useful; but it will be fruitful only if the team can communicate on common grounds, and this requires that each member has acquired some knowledge beyond his own specialty.

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* George Sarton, The History of Science and the New Humanism, New York: George Braziller, 1956.

Even more important is the utilization of the mental and material devices developed by previous generations. They are the rules of methodology, mathematical tables, monographic material, and an impressive array of instruments used for observation, experimentation, and calculation. All these devices represent a treasure created by former generations--an inexhaustible treasure available to everyone who learns how to make use of it. The more we utilize it in research, the more productive it becomes.

Finally, attention must be called to the influence of general education on zetesis. In order to make research activities fully effective, a broad view that embraces wide areas of knowledge must be cultivated. It is important to disseminate not only the gist of discoveries, but also the course of their development from inception to accomplishment.

6.3. The Creative Processes

CREATO-MOTIVE FORCE AND CREATIVE IMAGINATION

A well-ordered research program and well-equipped laboratories are necessary, but they are powerless unless there is a mighty incentive in the form of original ideas. Just as the flow of a current in an electric circuit requires an electro-motive force, so the flow of original ideas must be sustained by a drive for which we have suggested the term "creato-motive force." It may be described as that property of the human mind, implemented by the central nervous system,which initiates and sustains the interplay of ideas, concepts, and images in the process essential for the discovery of new knowledge, the invention of novel devices (mental and material), or the production of original works of art. Since this process is zetesis, we arrive at the following definition:

> Creato-motive force is the property of the human mind which tends to initiate and sustain zetesis; and creative imagination is that part of zetesis which consists in the interplay of available knowledge with original ideas set in operation before inductive and deductive reasoning can advantageously cooperate.

Simple imagination reproduces sense images derived from earlier perceptions. The creative imagination combines these images into new units obtained as in a dream, spontaneously and uncontrolled. These combinations remain bare phantasies unless a third stage of "constructive imagination" sets in. It is controlled by the dominant purpose of correlating the new units with the old ones so that new levels of organization or understanding can be reached.

Modern descriptions of the creative stages in scientific production have been traced to Herman von Helmholtz* and to Henri Poincare.** Four stages are distinguished. The first is "preparation" when the creative thinker is gathering his raw material. The second stage of "incubation" follows; the problem is laid aside and receives no voluntary attention until a time arrives to take up the problem again and achieve some progress. The third stage, that of "illumination" or "inspiration," is reached when the ideas become definitely related to a specific goal. Finally, with the fourth stage, "elaboration" or "verification," the ideas clarified in illumination are developed and revised until a satisfactory solution is obtained.

At present the analysis of creative imagination falls within the domain of psychology and neurology. It is based on three main methods. One is introspection. Psychologists who are interested in the processes of creative thinking collect factual material by asking artistically active persons, research scientists, and inventors to tell them about their experiences, about the inception of their ideas, and about circumstances which helped overcome their major difficulties. Another method of studying creative imagination is by correlating it with various psychological tests. The third method is neurological and consists in experimental studies of the structure and function of those areas of the central nervous system which bear a relation to imagination.

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* Vortage und Reden, 5th ed., Braunschweig F. Vieweg & Sohn, 1896.

** Science et Methode, Paris: Flammarion, 1908, p. 314.

As a contribution to the investigation of creative imagination by the first method, I offer my own early experience, as described in an interview with Mr. Rossman:

> Inventing seems to me to consist in the unconscious act of continual permutation of organized bits of knowledge I acquire by experiments and study. There seems also to exist in my mind some kind of mechanism operating unconsciously to filter out of consideration those experiences and impressions which are not directly related to the particular problem my mind is occupied with. So, for instance, I cannot read systematically at those periods, but usually glance through books and journals, noticing at once on the page just those words which directly concern the problem.*

As I understand it, one of the essential operations of creative imagination is a subconscious interconnection of ideas. In our memories, records of passing events and experiences are stored for future use. The processes of studying, abstracting, and reasoning add their contributions to this store. There must also exist a way by means of which these records can be recollected as needed. For we do not recollect our experiences haphazardly. As by an impulse in a relay of a selector, certain areas of our memory are "triggered" by an emotional condition or by association with some impression or experience of the moment. Being aware of a problem influences this process by orienting the various parts of the records, so that only those stored elements are selected which are pertinent to our objective. This selection, conscious or subconscious, may be called teleological or goal directed.

Out of these selected elements, images are formed which may appear essential for achieving our ends. Whenever a significant part of our problem has been clarified in our mind by striking the right combination of patterns, we immediately realize it. This may be the basis for the well-known phenomenon of a "flash," sometimes called "hunch," "intuition," or "inspiration." Such subconscious creativity may be accompanied by a prolonged concentration of attention on a definite aim, making it impossible to be mentally aware of anything but what is pertinent to that objective. Many of the steps regarded as subconscious may, thus, be merely out of the center of attention during the time which is called the period of incubation. A "flash" signifies the discovery of a satisfactory answer to the quest of the mind and the beginning of a constructive stage which by logical steps leads to the solution of the problem.

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* J. T. Tykociner in Joseph Rossman, The Psychology of the Inventor, The Inventors Publishing Co., Washington, D.C., 1931, p. 112.

The terms relay and selector are borrowed from the communication branch of electrical engineering. They need not be taken as entirely figurative, however. Recent advances made in neurology indicate that the brain with its myriad of neurons, synapses, and axons (forming interconnecting circuits and producing new conductive paths by conditioned excitations) is the seat of a highly organized electrical intercommunication center. What is known of its operation suggests a semblance to an electronic storing, selecting, and calculating device.

The investigations of McCulloch, Von Foerster, Gerard, and others, have brought out the role of electric phenomena in the activity of the brain as a central organ controlling, harmonizing, and integrating the functions of the body through the senses, memory, and imagination.[*] In Gerard's words,

> Electrical fields have been richly demonstrated in brains; have been shown to vary their pattern with state of activity, chemical environment, drug action, and the like (Gerard); and have been successfully invoked to explain in detail a variety of optical illusions in man (Kohler). By such various mechanisms, then, great masses of nerve cells--the brain as a great unity--act together; and not merely do two or a billion units sum their separate contributions, but each is part of a dynamic fluctuating activity pattern of the whole. This is the orchestra which plays thoughts of truth and beauty, which creates creative imagination.

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[*] W. S. McCulloch and W. Pitts, "A Logical Calculus of the Ideas Immanent in Nervous Activity." Bull. Math. Biophys. 5, 115 (1943) H. Von Foerster, "Quantum Mechanical Theory of Memory," Transactions of the 6th Conference on Cybernetics, 1949, Josiah Mach, Jr. Foundation, New York, 1950, pp. 112-45.

It is helpful to picture the parts of the brain associated with memory as analogous to a special living library comprising within its structure a collection of symbols which represent bits of recorded knowledge. These are organized into what may be compared to various catalogs and cross indexes. A system of interconnected nerve paths is partly inherited and partly developable by a constant inflow of new entries related to new experiences and ideas.

Thinking is a process of arranging and rearranging one's knowledge into an ordered system according to one's needs. Let us imagine the owner of such a library and his activity. He is busy adding more bits of knowledge accumulated by learning and every-day observations. These additions will not all be of equal significance. Some bits of knowledge impress him more than others, and these will be more easily recalled. The kind of knowledge which prevails in his collection depends on his mentality, education, and interests.

If the owner is a researcher or artist, he will become interested in a particular problem. First, he will formulate the problem and divide it so that each part can be treated separately. His creative imagination will tend to become adjusted like a sensitive compass in a mentally active field to indicate the right direction to his goal. It will remind him when he is deflected from his objective, so that he may rectify deviations in his search. Second, he will try to improve his communication system in order to classify bits of knowledge in a way which will make it possible for his memory to recall pertinent facts and ideas and to skip the unimportant ones.

This process of recalling is a selective one. It does not follow any chronological sequence. It is more like a kind of persistent searching in a maze made up of ideas and particular bits of knowledge already recorded or freshly acquired. It is always looking towards a combination which might give a clue to the solution of the whole or a part of his problem, thus

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R. W. Gerard, "The Biological Basis of Imagination," Scientific Monthly, June 1946, Vol. 62, No. 6, p. 496.

establishing a link with other parts. Whenever such a link is established, the most difficult portion of the process is over, and he becomes conscious of the direction in which he should proceed along the standard paths provided by inductive and deductive methods.

CREATIVITY AS AN ABILITY

Creativity has been studied under various names: creative imagination, creative insight, creative intuition, and creative thinking. In recent psychological literature, creativity is usually treated as an aptitude for originating and producing scientific, technological, or artistic innovations. However, a controversy is still current among psychologists as to whether creativity is a specific ability discernible by tests or just a level of general intelligence.

From the point of view of zetetics, it is important to find out whether creativity is a wide-spread ability among humans and how it can be developed. Furthermore, in order to increase the efficiency of various research activities, methods of occupational guidance are being sought which will facilitate the assignment of particular phases of zetesis to researchers endowed with suitable abilities. In some individuals the ability for mathematical analysis predominates, while in others the visual imagination of concrete things is more conspicuous. In other words, the specific ability of each researcher should determine the type of investigation which he undertakes.

Accordingly, one would expect the abstract thinker to be the most productive in theory; the keen observer, in collecting data; the systematic and punctilious, in ordering and classifying data; the concretely imaginative, in experimentation; the practically imaginative, in applications; the visually associative, in design; and the manually talented, in techniques. It is seldom that these qualities are all present and equally strong in a single individual.

The main interests of zetetics are reflected in the following questions: What are the qualities essential for the various forms of creative activities? And how can these qualities be determined by reliable tests?

An enormous number of investigations regarding human abilities have been carried on during the last thirty-five years. The work initiated by C. Spearman has proved especially fruitful insofar as it has introduced an analysis and a new doctrine designed to correlate the results of various psychological tests. His mathematical approach turned out to be most useful. The methods of factor analysis were employed in a way which made it possible to correlate the scores from multifarious tests which were designed to bring out various traits characteristic of large groups of individuals. Spearman's tetrad equation was used as a criterion to discover whether a series of such experimentally obtained correlations can be interpreted as a characteristic factor of an ability. For this purpose, a "hierarchical table" was drawn up, representing inter-test coefficients of correlation arranged in the order from higher to lower values.

In Spearman's words,

> Whenever the tetrad equation holds throughout any table of correlations, and only when it does so, then every individual measurement of every ability (or any other variable that enters into the table) can be divided into two independent parts which possess the following momentous properties. The one part has been called the "general factor" and denoted by the letter g; it is so named because, although varying freely from individual to individual, it remains the same for any one individual in respect to all the correlated abilities. The second part has been called the "specific factor" and denoted by the letter s. It not only varies from individual to individual, but even for any one individual from each ability to another.*

As a further advance, a multiple-factor analysis was introduced by L. L. Thurstone for the isolation of primary traits.** This work was followed by a wide range of experimental investigations which supported his theory.*** Once the primary factors are obtained, their interpretation leads to the establishment of personality profiles. The work of Cattell is noteworthy in its various approaches to the determination of the personality profile of the typical researcher.* The works of neurologists, psychiatrists, and geneticists are also contributing to the studies related to creativity. All such endeavors indicate that the time is near when definite answers will be obtained to the questions posed above.

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* The Abilities of Man, Their Nature and Measurements, The MacMillan Co., pp. 74-75, 1927.

** The Vectors of Mind, University of Chicago Press, Chicago, Illinois, 1935.

*** Primary Mental Abilities, University of Chicago Press, Chicago, Illinois, 1938.

Much thought has also been given to the problem of devising means of discovering talent. Personality profiles offer only partial clues. A profile suggests something established. More relevant would be something like a "line spectrum," that is, a picture which would show on a background of general abilities certain qualities growing and developing in an individual under the influence of education and environmental conditions.

To get such a graphic picture, let us imagine a coordinate system as shown in Figure 6. 1, with various abilities represented by points a_1, a_2, a_3, etc., along the abscissa. The ordinates indicate the relative power for each ability. The median powers statistically derived from scores based on a very large sample of individuals would be marked by corresponding points (m_1, m_2, m_3, . . .) lying above the axis of abscissa. Data on the power of abilities obtained by investigating a single individual could then be plotted (P_1, P_2, P_3, . . .). For comparison with the medians, lines could be drawn (P, m) parallel to the axis of ordinates, some of these lines rising above and others falling below the median points. Taken in their entirety, these lines would represent a "line spectrum" characteristic of the abilities of this particular individual at a particular time, and comparing his abilities with those of the group. If the scores were all measured in standard scores, the medians would be equidistant from the abscissa, and various abilities would be directly comparable. Such spectrograms, taken repeatedly over a period of years, would give

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* R. B. Cattell and J. E. Drevdahl, A Comparison of the Personality Profile (16 P. F.) of Eminent Researchers, British Journal of Psychology, Vol. 46, Part 4 (Nov. 1955), pp. 242-61.

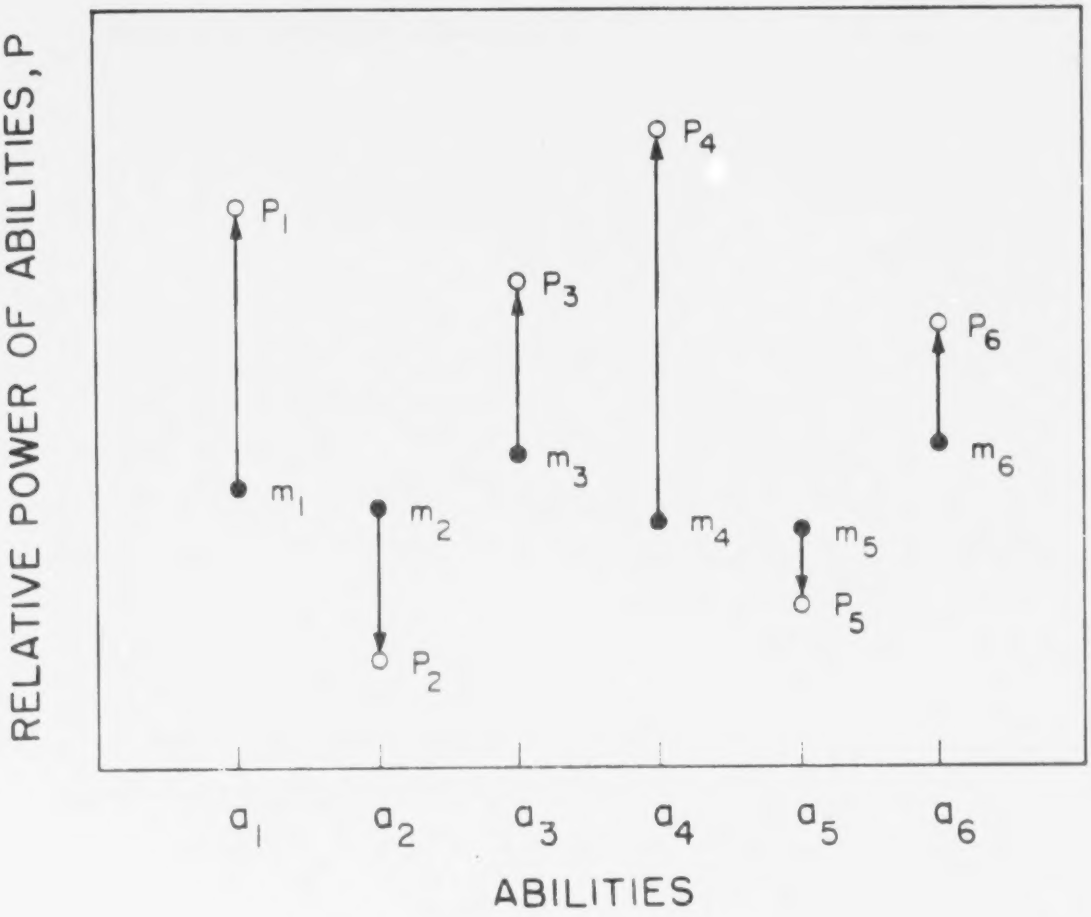

FIGURE 6. 1. SPECTROGRAM OF ABILITIES

a comparative picture of abilities as a function of age, education, and environment. I would like to recommend this "line spectrum" approach to the many research teams who are involved in the experimental studies of creativity.

Perhaps use could also be made of the new techniques of electroencephalography, the neurologist's new tool for investigating electric waves produced by the activity of the brain. Might not the wave form, frequency, and relative amplitude distribution of such brain waves supply the clues needed for determination of the abilities entering into the process of zetesis?

RELATION BETWEEN CREATIVITY AND INTELLIGENCE

Is the gift of creativity identical with that of intelligence? Do IQ tests reveal creativity or is it only one of many aspects of intelligence? If it is only one aspect, should it not be studied apart from the intelligence quotient metric? These questions are of basic significance and stimulated many large-scale theoretical and empirical investigations carried out during the last few decades. Researchers hoped, but were not able, to clarify the relation between creativity and intelligence.

My own observations at the University of Illinois (between 1921 and 1942) led me to doubt whether good grades and high IQ were reliable indicators of creativity. Many of the graduate students who were regarded as exceptional and who earned high grades were endowed with excellent memories, but they lacked originality. Their ways of thinking depended merely on what they learned from textbooks and classroom notes. When confronted with research tasks they were inclined to treat them as quizzes to be answered by searching textbooks. They were perplexed when told that research consists in discovering new phenomena, inventing novel devices, and investigating as yet unknown relations.

The results of recent studies tend to confirm the fact that a high "intelligence quotient" is not necessarily characteristic of creatively gifted students. The IQ metric has proved useful as a means to predict academic achievements. However, especially designed metrics had to be developed to identify the more elusive quality of creativity.

For instance, in a comprehensive exploration with a group of gifted students whose IQ was higher than the average, the investigators using "creativity metrics" could identify two significant types of cognitive giftedness.* Some members of the group were able to perform very well problem solving tasks used in conventional IQ tests, but they did not perform as well tasks designed to indicate creativity. In contrast, members of the group representing a second type revealed better performance in the "creativity" test and less excellence in the conventional IQ test.

The social-personal characteristics of the students showed a remarkable correlation with the above classification. According to the test, the high-IQ type tends to concentrate on the usual and is apt to choose the already accepted rather than to risk the uncertainty of the unexplored. In contrast, the highly creative type is attracted by the unknown and is drawn toward emancipation from the usual.

There was still another significant difference between the two types revealed by these tests. Each subject was asked to specify the occupation he would choose. The quantity of occupational possibilities was greater for the high-creativity type. They enumerated unconventional occupations like writer and inventor, while the high-IQ type listed conventional occupations like lawyer and physician. Thus, these tests give some insight into the aspirations which distinguish the two types of gifted students and indicate the differences in attitude regarding their life's work.

6.4. Factors Essential in Zetesis

DEVELOPING CREATIVE ABILITIES

Here we are confronted with the question of how to develop the power of creativity and avoid blocking it once it has manifested itself in an individual through tests or actual performance. This is a field very little explored as yet; however, it is known that creativity can be stimulated by encouragement, supported by opportunities to exercise the creative skills, and intensified by proper environmental conditions.

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* Jacob W. Getzels and Philip Jackson, Creativity and Intelligence, John Wiley & Sons, Inc., New York, New York, 1962.

Creativity is an ability more apparent among school children than among adults. Is this due to decrease of creativity with age or can its deterioration be ascribed to repressions and environmental conditions which counteract the creato-motive force? Many facets of this question cannot be mentioned in such a brief discussion as is included here. However, a few lines should be given to the main obstacles which hinder the productivity of creatively endowed persons.

Psychiatric evidence has brought to light various circumstances which block creativity. They are to a great extent based on inner conflicts which arise when a creative mind tries to adjust itself by balancing established views accepted by others and himself with contradictory views which his creative imagination has revealed to him. Then the joy usually accompanying creative illumination becomes painful and sometimes even frightening.

Another devastating influence is the boredom so frequently experienced in family and social circles and in schools and universities whenever disconnected subject matters are presented in a dull way, isolated from knowledge as a whole, and without enough insight to evoke enthusiasm for the role knowledge plays in human affairs. So long as motivation for the acquisition of knowledge is reduced to a mere race for better grades, degrees, and honors, there is little chance to develop a passion for the great adventures which lead to increasing our cultural heritage by original contributions.

CRITICAL ATTITUDE

Creativity requires independence from preconceived ideas. Living in a dynamic world where old and new ideas clash with one another, an open-minded person must acquire the art of weighing arguments. He must know that views and theories, including beliefs, are based on experience and that experience depends on circumstances and facts. New facts must find a logical place in his existing scheme of views. If they cannot be coordinated with what he assumes to be true, this signifies a defect in his assumptions. This defect must be either corrected by changing his premises and concepts or avoided by finding another point of view where the new fact will fit into its proper place.

Only by an open-minded attitude can knowledge be gained in any field. This does not mean, however, that all new ideas should be accepted uncritically. On the contrary, they should be carefully analyzed, taking into account all the new facts and arguments for and against. The result usually is that old ideas, as well as new ones, have to be modified. Such changes are difficult to make and to carry through by reasoning alone. Emotion plays an important part, and even strictly scientific theories are often developed under the pressure of a passion for getting at the truth.

The very concept of creativity is connected with originality in ideas as well as with new ways of associating new facts or concepts with accepted knowledge. Thus, "creato-mindedness" is the opposite of closed mindedness which shuts off the world of thought from interacting with fresh concepts and makes one's mind incapable of extending its range of vision.

Here the question might be raised: How is a transition made from old to new knowledge? This happens when the creative mind adopts a critical attitude toward prevailing concepts. Then the creato-motive force impels the researcher to devise a new theory which eliminates existing inconsistencies, such as those between the Newtonian concepts (constant mass, absolute space, and absolute time) and the more recent empirical findings. However, the records of Galileo's, Newton's, and Minkowski's work were prerequisite for Einstein's general theory of relativity. Likewise, the work of the Curies, Rutherford, and others was a prerequisite for the work of Fermi and the whole galaxy of present-day nuclear scientists. Thus, the production of new knowledge begins with a critical attitude, followed by a revision of previous concepts and the creation of a new theory from which new facts may not only be predicted, but established by further activity of the creative imagination.

COINCIDENTAL CIRCUMSTANCES

Does a critical attitude toward prevailing concepts and theories always precede the creation of new knowledge?

There are many ways by which the creato-motive force initiates the interplay of ideas which lead to the formulation of problems and the creation of new knowledge. A critical attitude, as mentioned above, is one of these ways. Inquisitiveness is another. A list of unsolved problems usually excites the imagination of gifted individuals. Problems are also suggested by listening to lectures, by reading, by participating in discussions, and by observing unusual phenomena in the laboratory. Many secondary problems arise while carrying out plans for a large-scale investigation.

However, history offers examples of how discoveries and inventions originate without previous planning. One often "comes across" problems which lead to new developments. But these cannot be regarded as entirely accidental. To a mind not endowed with inquisitiveness and not receptive to new phenomena and concepts, the so-called "accidental" discoveries never occur.

Generally, two kinds of chance are influential in the process of creativity. One kind consists in the coincidence of two ideas which fill a gap in our thinking. It is the more general occurrence and may be called the psychological chance. The other kind is the coincidence of two external events which strike our attention and lead to a fruitful discovery, a new artistic pattern, or a technological innovation. It may be called the chance of external coincidences.

The term "serendipity" has been coined for the origin of discoveries made by "chance." It was suggested by Horace Walpole and is based on a fairy tale, "The Three Princes of Serendip." (Serendip is the ancient name for the island of Ceylon.) These princes set out on a journey of inquiry, but were always digressing, and as a result made discoveries that they were not in quest of.

An example of serendipity is the circumstances which led to the discovery of a giant meteorite crater in northern Canada.[*] In February, 1950, Fred W. Chubb, a prospector, was studying aerial photographs of the region between Ungava and Hudson Bay. These photographs, taken by the Royal Canadian Air Force in 1948, showed a flat tundra sprinkled thickly with little irregularly-shaped lakes. The prospector's attention was struck by one lake which was almost round and surrounded by a wall of rock. Chubb showed the photographs to Dr. V. Ben Meen, Director of Toronto's Royal Ontario Museum of Geology and Mineralogy.

Dr. Meen organized an expedition to investigate this lake in July, 1950. He found that it was a meteorite crater, the biggest yet discovered. The lake in the crater was still frozen at the end of July and there was no lava or other sign of volcanic activity. It measured two and a half miles across as compared with Arizona's famed meteorite crater which is only four-fifths of a mile in diameter. The ring of the crater, being lowest on the northwestern side, suggested that the meteorite came from that direction and hit the ground obliquely.

The crater has been justly named the Chubb Crater. He discovered it, although he was not looking for meteorite craters. In his search for other things, he "came across" something which excited his curiosity. He perceived what others had not noticed or had not regarded as significant. In fact, it had been photographed earlier by an American Army plane when on a weather flight in June, 1943, but had apparently attracted no attention at that time. But to Chubb one round lake among many of irregular shape meant that there was something unusual and worth investigating. His discovery was the result of keen observation paired with creative ability. A critical attitude was necessary, since without it Chubb would have overlooked the round lake or thought nothing of it.

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[*] V. B. Meen, "Chubb Crater, Ungava, Quebec," *Proceedings of Geological Association of Canada*, Vol. 4, Dec. 1951, p. 49.

My own experience illustrates how a critical attitude, combined with casual circumstances, can lead to an invention. I was sixteen years old (1893) when I became deeply interested in the recording of sound and made simple experiments with a primitive form of Edison's phonograph. Soon I became disappointed and extremely critical. I thought the distortions of sound were unavoidable with a membrane and a recording needle. How to get rid of the needle and of other mechanical means of recording and reproducing sound was the question which occupied my thoughts. One day the answer flashed through my mind, namely, that it could be done with photographic recording and by the use of a selenium cell for the reproduction of sound. This happened during my first transatlantic passage from Antwerp to New York in March, 1896. When I landed I already had sketches of various details for my "ideal phonograph." Unfortunately, photographic films and photosensitive cells were not available at that time, and this greatly hampered my experiments.

Nonetheless, recording sound photographically and reproducing it photoelectrically in connection with motion pictures soon became the main focus of my thoughts. To relate the circumstances which led me to the invention of sound motion pictures, I will quote a passage from my article published soon after my first public demonstration of sound pictures at the University of Illinois in Urbana, June 9, 1922.

> Strolling through the business center on Broadway (in 1897), I came across a large sign inviting people to come in and see the latest wonder, the Bioscope. I walked in and saw projected upon a small wall screen athletic, military, and simple dramatic scenes. It was the first time I saw motion pictures. In a dark room marching soldiers were seen on the wall, performing movements under the command of officers. No sound was heard other than the clicking of the projecting machine.
>
> I was impressed by the technical achievement, but the absence of sound made the show unnatural, and the mute dramatic scenes seemed to me unendurable. The necessity of sound, and especially speech, in addition to the visual illusion was so manifest that I could not help associating the working of my new phonograph combined with the projection of moving pictures. While returning uptown in the rattling elevated

> railroad, I had ready in my mind a scheme of photographing sound, at the same time with moving pictures, on a common film and reproducing the sound simultaneously with projecting the picture upon a screen.*

What I did not realize in 1897 was that the knowledge of amplifying extremely feeble electric currents was still lacking. Twenty-five years of development had to pass before appropriate amplifiers and loudspeakers came into existence. Only with these missing links added to a long chain of inventions could I succeed in solving the problem of sound motion pictures in its entirety.

The "accidental" in this case was the occasion to see a Bioscope showing the first silent motion pictures. However, since my mind was already set on various applications of the photographic recording of sound, it was quite probable that even without any such suitable accidental occurrence I would have arrived at the idea of sound motion pictures. But it is a known fact that suitable circumstances and advantageous environmental conditions stimulate and accelerate the fruitfulness of creative imagination.

IMPORTANCE OF INTROSPECTION

Encouraging as are the over-all advances which have been made in the study of creativity during the last quarter of a century, available factual material is still insufficient for developing a satisfactory theory of creative imagination. It is desirable that, in addition to experimental studies, facts obtainable by introspection be further collected. Everyone active in any field of research should regard it as his duty to keep in his notebook not only records of his work, but also a description of the circumstances under which his ideas were conceived. It is also necessary to have a description of how progress was furthered or retarded. Such case histories will become valuable for the development of the new area of knowledge, zetetics; they will enrich the materials already collected and published by scientists, logicians, psychologists, and historians of science; and they will be especially helpful in education for zetesis.

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* J. T. Tykociner, The World, Sunday Edition, July 30, 1922, p. 1.

At this point it seems appropriate to insert a description of the factors which led me to the conception of research as a science and to the investigation of the various aspects of research activity.

I joined the faculty of the University of Illinois in 1921 to do research in the Engineering Experiment Station. At the time I was very pleased with being allowed to engage in problems of my own choice, and I had in mind several which I intended to tackle. However, I soon learned that new ideas and enthusiasm were not enough to overcome the lack of budgetary means, laboratory space, and personal assistance. It soon became apparent that my real problem was to discover what could be done with the meager means at my disposal and then how to overcome the skepticism shown toward my enterprises.

My first research was the one I cherished most: photographic recording and photoelectric reproduction of sound and its use for sound motion pictures. I successfully demonstrated such sound pictures in June, 1922, but was not given any funds to continue this line of research in spite of the many possible applications for television and educational purposes foreseen at that time.

Thus, I had to choose another problem. It was a fascinating study, never undertaken before, of the use of short electromagnetic waves for the investigation of the properties of radio-antennas by means of small models. The course of events as in the case of sound on film repeated itself. A new and successful method of studying and developing new types of antennas was devised, but I found it impossible to continue the next important phases of the investigation. This time, in addition to the three fateful factors mentioned above, a fourth one decided the issue--namely, the cows. Yes, cows in the pastures located where the Assembly Hall now stands could not help interfering with short wave antennas whose radiation patterns and reflections were the objects of my studies. The point I wish to emphasize is that in this controversy the cows were the victors, for their function and destiny on the pasture were regarded as more important than mine in carrying forward research which, although no one suspected it at that time, could have led to the invention of radar.

In general, those times were unfavorable for university research. It was assumed that the ultimate purpose of state institutions of higher learning was to teach known things useful in agriculture, engineering, and commerce. Information as to what problems should be studied was gathered by inquiries in influential industrial circles. As a result, testing of industrial products was mistakenly regarded as the only research suitable for the College of Engineering. Problems of sound motion pictures and of sound modulation by variable sources of light were considered of no interest to the public. Likewise, the study of antennas and their radiation patterns by means of models was looked upon as of no immediate value. Actually, equipment and space for such field work were not even available within the grounds of the College.

I was thus confronted with the necessity of making still another choice of a research problem. I chose piezoelectricity; but, for the continuation of studies in piezoelectricity and its applications, expensive optical equipment soon became necessary. The cost of this was prohibitive in view of the meager appropriations accorded at that time to the Experiment Station. Finally, lack of precision machine tools, mechanics, and glass blowers blocked all attempts to continue building necessary apparatus and equipment for carrying on original research in this line.

When, in 1926, my experience became enriched with a fourth occurrence which similarly forced me to change my objective and look for still another problem, I began to wonder. What will happen if none of the problems that I am interested in fit into the scheme of adminstrative circumstances, so irrelevant to research as such and so disturbing in view of the fundamental questions in my mind? How should the selection of problems be made? What should be the sequence of research tasks? Is there a rational way of making a choice? What is the deeper meaning of research, its methods, and its purpose? Is it possible to set up a scheme which would do for all the sciences what the periodic table has done for physics and chemistry? What a grand thing that would be. If such a scheme could disclose glaring gaps in our knowledge, would it not lead us toward discoveries and inventions?

All these questions pointed out the fact that we were ignorant of an entire field of knowledge. To establish such a field seemed to me a most urgent problem. The beauty of it appeared in its universality; its most attractive feature was that such studying did not require either space or money. But was this a problem suitable for an Engineering Experiment Station? The answer was a tragic "No." Indeed, it could hardly be expected that an investigation so far removed from specific engineering problems would be undertaken by the Experiment Station.

Nevertheless, research as a science became established, at least in my mind. A part of its subject matter was described in a paper published in 1931 under the somewhat limited title, "Classification of Research Problems in Dielectrics."* Since 1926 my mind has been occupied with plans for a "Science of Research," but it was only in 1928 while preparing a lecture for the physics colloquiums on High Voltage Phenomena that several striking observations were coordinated in my mind and gave direction to further developments.

1) The first was connected with a sociologically interesting phenomenon which made its appearance early in this century and has become very pronounced during the last thirty years: the individual and independent scientist and the lonely inventor are disappearing from the field of research, to be gradually replaced by teams and groups of investigators. Such groups include members with a variety of talents, skills, and creative abilities; they work together in scientific institutes, research foundations, and industrial organizations with numerous well-equipped and spacious laboratories. Can there be any doubt that by uniting the endeavors of all participating members in a rational way such teams can more effectively produce new knowledge, develop inventions, and achieve

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* Transactions of the Illinois State Academy of Science, Vol. 24, No. 2, pp. 300-309, December, 1931.

a higher level of understanding?

2) The rapidly decreasing time interval between discoveries and their applications was the second observation. It appears that this phenomenon is directly connected with team work, especially with increasing contacts and cooperation between scientists and engineers in industrial laboratories. And these ties are becoming closer, with the result that often the interval of time separating industrial inventions from scientific discoveries disappears and occasionally is even reversed. Innovations are often introduced before the knowledge of related scientific facts is clear. Moreover, such cross-fertilization between basic and applied research and development becomes a new factor, producing a chain reaction in the growth of science and technology. But is not this rapid development rather one-sided, endangering economic, social, and international stability? And what are the factors which produce all these various tensions?

3) The third observation was that in the present way of selecting research problems chance determines the choice. Much thought had to be devoted to methods of systematization and selection of problems as essential aspects of a science of research, a step comprehensively treated in Chapter 5.

Thus, the coordination of the above observations made clear to me how important it is to find out what basic processes and principles underlie research, what the social function of research is, and how this knowledge could be best utilized when facing complex problems.

AUXILIARY AIDS

Anxiety is often expressed in connection with the increasing use of mechanized devices, especially in research. The introduction of "electronic brains" evokes fear of deteriorating mental abilities. But little progress could be made in advancing our knowledge and arts, if everything which the human kind produces had to be reinvented for each exigency. It is the outstanding significance of culture that it preserves and transmits the invaluable results produced by generations of creative minds. Knowledge of these results, combined with adequate use of the tools for thinking, enables the human mind to undertake the solutions to new problems.

The human organism could hardly function in a harmonious manner without making use of a number of automatic devices with which it is equipped at birth. We do not need to think about the circulation of our blood, or the maintenance of a constant temperature in our body, or the regulation of our breathing in accordance with our physical efforts. All these tasks are attended to by homeostasis--the automatic functioning of a combination of those inherited physical, chemical, and neurological devices--without any intervention of our will or intelligence.

Regarding adaptation to new conditions, there is an analogy, if not quite an identity, in the way bodily activities of individuals and the cultural functions of human aggregates operate. In order to survive, individuals, nations, and mankind as a whole have to develop at an increasing rate new means of combatting dangers. This is done initially by taking care of each case separately as it is encountered. However, if a certain kind of danger multiplies in frequency and persists over longer periods, special protective organs develop to prevent individuals or even the whole society from succumbing to these new conditions. In this process, genetic mutations and natural selection are operative in establishing new interconnections between existing organs, so that the whole can act automatically.

Similarly, whenever exigencies arise and the preservation of a group requires the introduction of a new device or function, ways must first be developed by the direct activity of creative intelligence. Once the solution has been found, means are devised to automatize this new function, to emancipate the human mind from the drudgery of endlessly repeating routine work. The mind is thus made free to apply its creative power to unsolved problems.

From this point of view, it is a fallacy to assert that in our age we are replacing thinking human beings by machines and automats. What the latter actually accomplish is just to release humans from those aspects of manual and mental work which can be performed faster, with more precision, and with less effort by devices especially invented for that purpose. Thus, time and effort, otherwise spent on trivial tasks, can be devoted to implementing creative ideas and to the enjoyment of a fuller cultural life.

6. 5. Conceptology--Concepts and Their Role in Zetesis

In Section 3. 4 and Table 3. 1, steps in the evolution of a science are briefly described and enumerated. The last item of this table refers to the transformation and metamorphosis of a science due to new concepts. It is indeed the role of fruitful concepts to initiate the new developments which produce radical changes in existing sciences, open trails to new ones, and eventually lead to the formation of new areas of knowledge.

New concepts must be invented, theoretically developed, and experimentally verified. If they help to eliminate gaps in our knowledge and can predict new verifiable facts or phenomena they triumph over the old concepts which then become obsolete.

Conceptology is the name I have chosen for the study of the formation, application, dissemination, and elimination of concepts throughout their life cycle in the evolution of the arts and sciences.

Conceptology is thus based on records from the history of science which show that many fundamental discoveries were made by substituting new concepts for old ones. For instance, in geography the change from the concept of a flat earth to the concept of a spherical earth brought about a revolution in geographical explorations. As a consequence, new continents were discovered, new trade routes were established, geodesy was developed, and the science of navigation was built on new foundations.

Also significant is the way knowledge of heat phenomena was advanced by discarding the concept of "phlogiston" as the basic material substance of combustion. The concept of heat as radiant energy which sets atoms and molecules in violent motion and produces collisions was substituted for it. Combustion was then seen as the disruption of the molecules of combustibles and the resulting formation of heat producing chemical reactions. The change of concept in this case resulted in a better understanding of the origin of heat in the process of combustion itself and also led to developments in thermodynamics, the invention of internal combustion and heat engines, as well as other innovations.

A revolution in physics and chemistry was effected by the introduction of Planck's concept of the quanta as the basic unit of energy. Many examples could be given from other areas--the biological, the psychological, etc. --to testify to the significance of new concepts in the development of the arts and sciences. The preparation of a list of such concepts was the starting point for my study of conceptology. The work of Carl G. Hempel is a significant step forward on the problem of concept formation.*

Concepts are auxiliary mental tools for facilitating cognitive activities. In daily life, concepts are acquired from parents, teachers, the environment, etc., and influence our behavior in the earlier stages of development. Once a concept is established in the mind, it becomes habitual and hard to change. It affects our ways of thinking and often impedes creativity.

The identification of certain concepts with truth is a great obstacle which plagues humanity. This creates antagonism between the groups of a society, ill-feeling between nations, and misunderstanding between learned groups such as scientists, artists, engineers, and scholars.

One of our serious problems is how to avoid blocking the searching mind by archaic concepts which delay development, especially in research and artistic activities where the generating of new concepts could play a useful part in the solution of important problems.

Conceptology may be regarded as a link between zetesis and general methodology. It is also related to homologic symbolics.

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* Carl G. Hempel, "Fundamentals of Concept Formation in Empirical Science," Vol. II, No. 7 of International Encyclopedia of Unified Science, University of Chicago Press, Chicago.

CHAPTER VII

zetetic [illegible]

GENERAL METHODOLOGY

7.1 Definition and Role of General Methodology

Once a problem for investigation is carefully selected and precisely defined, we are confronted with the question: What ways may lead us to its solution? This is the question methodology attempts to answer. We can hardly expect to obtain a complete solution to the problem, but we must seek to advance our knowledge by consecutive steps which may at least lead to a partial solution. The knowledge thus gained is in itself valuable as a means for further progress towards our goal.

So long as the various parts of the arts and sciences were not looked upon as interconnected and were therefore treated independently, methods of investigation were developed to suit only particular, narrow branches of knowledge. But zetetics is concerned with knowledge as a whole and therefore seeks to synthesize all available methods of research. General Methodology treats those methods which are applicable to all of the arts and sciences.

Methodologies have been studied from various angles for ages, especially by logicians, who have made the most valuable contributions. Since Francis Bacon's emphasis on the experimental method of searching for new knowledge, the inductive method has assumed growing significance, resulting in what is called the scientific method.

It would seem appropriate to start the discussion of this section with a review of what is meant by the scientific method. Unfortunately, there is a variety of interpretations concerning this concept. Some prominent men of science even deny its existence. The confusion is mainly due to the multiplicity of meanings given to the words "scientific" and "method."

Since this is an outline of zetetics, we will bypass the controversy by stressing the zetetic aspects of general methodology. According to our definitions, science is the totality of systematized knowledge so far accumulated. For the process of increasing knowledge the concept of zetesis has been introduced. Thus, the adjective "scientific" refers to already known knowledge and is inapplicable to activities tending to increase our knowledge. As to the word "method", it is often identified with procedure and technique which vary with the subject matter of each particular science.

It will simplify our discussion considerably if we avoid altogether the use of the term "scientific method" and define "general methodology" as

> that part of zetetics which studies the logical operations essential in all research and artistic creativity.

7.2. Elements of Systematized Knowledge

We can obtain a general idea of the structure of systematized knowledge if we break it down into its elements. In the following list, these elements are enumerated together with an explanation of their meaning. Each element is based on the preceding one and is itself the basis for the following, more complex one.

Bit	- smallest unit of information, as used in the theory of communication
Event	- group of bits forming an intellectually challenging single occurrence
Data	- series of recorded events interconnected by controlled uniformity of conditions
Fact	- a repeatable series of data suggesting a class

Class	- a group of facts showing common characteristics
Rule	- preliminary deduction on the basis of empirical correlation within one class
Generalization (law) *	- rules reduced to a statement covering two or more classes
Theory	- a body of generalizations formulated by means of consistent concepts so interrelated and unified that it embraces events, data, classes, and generalizations into a single system capable of predicting unknown facts by deduction
Truth	- a theory capable of interrelating all areas of knowledge into a consistent integrated system. It is relative; it refers to the growth of knowledge, asymptotically converging toward completeness. Absolute truth can be regarded only as a concept--an ideal whose realization is limited by the capabilities of the human mind

Although the enumerated elements are components of the structure of knowledge, in themselves they do not create new knowledge. It is the interplay of these elements with the functionally interconnected parts of zetesis, as defined and enumerated in the previous chapter, which creates new knowledge.

The majority of the above elements are self-explanatory, but some need clarification. Data are generally assumed to represent the primary rough material of observation, as objectively and truly recorded as possible. On the other hand, facts represent data processed intellectually by comparison and differentiation so that they show a certain temporal and/or spatial regularity. The transition from data to fact is a step toward understanding a process.

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* So-called laws are generalizations formulated on the basis of knowledge as it exists at the given stage of development. Since this term suggests man-made legal rules, it is not used in this discussion.

For instance, in meteorology readings from a thermometer suspended outdoors represent data, while an inspection of the curves representing the data reveals characteristic rises and falls of temperature which indicate a fact connected with the process of heat radiation from the sun. Thus, the enumeration of temperatures observed at definite hours supplies data. The curves yield the fact that on a clear day the temperature rises during the day, reaches the maximum in the early afternoon, and decreases in the evening.

Data collecting and fact finding, like all other steps in zetesis, are undergoing development to increase precision, economy of effort, and reliability. We must mention to illustrate this trend that in nearly all sciences of the hylenergetic, biological, and pronoetic areas automatic equipment is being widely introduced in place of manual recording. Furthermore, unmanned self-activating devices have been invented which are distributed over the earth in inaccessible regions. They are supplied with telemetering devices to transmit data continuously to central points. Thus, astrophysical, meteorological, seismographic, radiological, hydrographic, and other data are automatically recorded and transmitted.

Since October 1957, a notable extension has been introduced into the technique of fact finding by satellites launched into space. They serve as automatic observatories by broadcasting information valuable for many fields of science and technology.

Characteristic of modern developments in fact finding is the increase in the number of special institutions like the Smithsonian, the Bureau of Standards, and the Census Bureau which gather data on such things as the sun's radiation, radio wave propagation, population movements, economic trends, and health conditions.

During the last decade, data processing and computing devices have been introduced. Designed for speedy recording and for the converting of data into pertinent facts, these techniques have greatly enhanced the efficiency of zetesis. They supply the means for treating data flowing in at such high rates and large numbers that it would otherwise be impossible to handle. Researchers, having been thus relieved of tedious routine work, are now in a position to devote more of their time and talent to other essential aspects of their problems. Thus, their chances of making valuable contributions have been enormously increased.

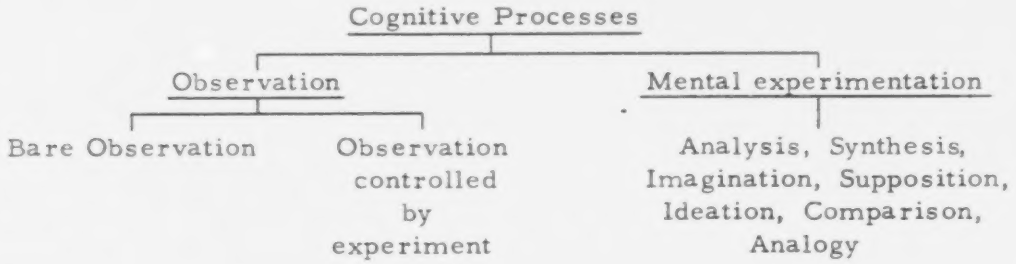
The term "rule" also needs clarification. Principles are often confused with rules because they are only slightly more comprehensive. For our purposes, however, "generalizations" include what is normally referred to as a principle. In electromagnetics the "right-hand screw rule" indicates the relative directions of the magnetic field, electromotive force, and motion. In optics the Fermat principle (or generalization) correlates the minimum and maximum time which beams of light require to travel from one point to another under various conditions. In dynamics the Maupertuis' least-action principle and Le Chatelier's least-energy principle may be mentioned. Rules are usually obtained by correlating regularities which appear in the study of series of measurements. Thus, the rules which correlate wave length of radiations obtained by spectrometry played an outstanding role in the theoretical development of atomic physics and led to quantum mechanics.

In other areas of knowledge, the anthropologist's statements that in tropical regions the populations are dark skinned and dark eyed, and in the northern regions, close to the Arctic Circle, they are prevalently light skinned and blue eyed may be regarded as rules. Also a rule is the economist's observation that during depressions the price index has a tendency to decline.

7.3. Cognitive Processes

Operations with elements of knowledge, as they are described above, involve certain mental activities, which psychologists call cognitive processes. To these processes belong the following: bare observation, experimentation (which is controlled observation), analysis, synthesis, imagination, supposition, ideation, comparison, and analogy. Experimental psychology has extended the principle of psychophysical parallelism by showing the close interrelation between mental and neurological activities. Ever since the inception of a science of research, I have been inclined to look upon cognitive processes as interaction of sense experiences with data, facts, and concepts. This view, limited to mathematics, is supported by two books which were published recently: G. Polya in his two-volume work on Mathematics and Plausible Reasoning refers to the role of induction and trial-and-error methods in the development of mathematics;[*] and A. I. Wittenberg gives a thorough analysis of mental experimentation, as applied to mathematics, in his book entitled Von Denken in Begriffen, whose subtitle translated into English is "Mathematics as an Experiment in Pure Thinking."[**]

These views, if extended to all of the cognitive processes related to zetesis, may be expressed in the following schematic way:


Cognitive Processes
Observation
Mental experimentation
Bare Observation
Observation controlled by experiment
Analysis, Synthesis, Imagination, Supposition, Ideation, Comparison, Analogy

The term "ideation" refers here to the activity of forming ideas, especially abstract ideas.

From this point of view, thinking in research is a process of mental experimentation conducted by arguing with oneself. To do it efficiently, the researcher needs the resources of language, logic, and mathematics, and he must use systems of images, symbols, axioms, and concepts. Such mental experimentation may lead to fruitful deductions and the production of new facts. Imaginary dialogues written by Galileo and by ancient Greek philosophers represent records of introspection guided by this type of experimentation.

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[*] Princeton University Press, 1954.

[**] Birkhauser Verlag, Basel, 1957.

It need hardly be mentioned that the relative participation of the nine enumerated cognitive processes depends on the intellectual character of the researcher and on the level the problem has reached at a particular stage of investigation.

7.4. Logical Aspects of Zetesis

The cognitive processes discussed above must be distinguished from the methods of logical operations. Any phenomenon which shows a change in time is a process--for instance, growth. In relation to mental activity, the process is a series of steps which, although directed to an end, need not necessarily be ordered. For instance, one's mind normally wanders unmethodically in an activity as simple as planning an extended trip, as well as in the initial stages of solving a research problem. A method on the other hand leads to ordered activity. It tells how to do something or how to proceed in a regulated way.

The characteristic role of the entire second area of knowledge, the symbolics of information, is to supply a means of treating data and facts in a logical way. No matter from what area of knowledge data and facts are drawn, they are subjected to the same principles of logic. The principles are helpful in ordering the data and facts, in drawing inferences from the conditions under which the investigated phenomena occur, in checking the consistency of concepts, and thus in enabling the researcher to interpret the phenomena with as little error as possible.

General methodology embraces all the particular logical methods. They are based on the work of logicians, like Bacon, Mill, and others, whose works were primarily expressed in verbal forms. But new methods of logic are now gaining significance and usefulness by the introduction of mathematical forms, often called symbolic logic. This new logic is made possible by developments in mathematical logic and the philosophy of science.

In this outline only the most important logical methods based on syllogisms can be mentioned. They are

✓ a. classification,
✓ b. description,
✓ c. statistical method,
✓ d. genetic (evolutionary) method,
e. inductive methods, including
    1. the method of difference,
    2. the method of concomitant variations,
    3. the method of agreement,
    4. the method of residues,
    5. joint method of agreement and difference, and
✓ f. the deductive-inductive method.

Parallel to the development of logical methods, means are being discovered for performing routine logical operations by "electronic brains." Thus, further economy in mental effort, which will lead to increased efficiency in research activities, is in sight.

7.5. Classes and Types of Research Problems

It may appear that the four interconnected parts of zetesis discussed in the previous chapter represent a straightforward, step-by-step process starting with the initiating impulse and leading directly to the solution of a research problem. Actually, however, they serve only as a framework for the elements of knowledge and indicate only briefly the cognitive processes which constitute zetesis.

Essential as these processes are, they only prepare the ground for the tortuous ways which even a most talented researcher has to take in his attempts to solve a problem. The variety of research problems is overwhelmingly large, and records showing how their solutions were obtained are scarce. No wonder that each researcher follows his own individual way, which in many cases he does not attempt to bring to his consciousness, much less to present in a general outline usable as historical material for the study of zetetics.

It is, indeed, one of the tasks of zetetics to gather such material, to set up classes of research problems, and to investigate each class from the point of view of possible ways leading to the solution of its problems. Let us, therefore, describe the prevailing classes and types of research problems.

Researchers classify various observed phenomena as physical, chemical, psychological, historical, sociological, aesthetical, etc. These are the larger divisions which have become the subject matters of distinct arts or sciences. Classes of observable facts are obtained by searching for common properties and also for those characteristics which make phenomena differ from one another. Some phenomena lend themselves to direct observation; others require more or less complicated techniques; still others, like those in meteorology and geology, are spread over vast areas or, like historical events, sociological processes, and artistic tendencies, extend over long intervals of time.

Important as the various observational techniques in many fields may be, they are secondary matters in comparison with the functional characteristics of research. The latter are independent of the field of investigation, as we will show later. They require that all observations be so ordered that they can serve for making valid conclusions pertinent to the solution of the given problem. Of course, much depends on what we define as a fact or a class and on the particular concepts we apply. Here is where the philosophy of science comes in. If our concepts are faulty, the ordering of data--however reliable they may be--will not enable us to draw correct conclusions. But concepts can be readily replaced by more appropriate ones. The history of science supplies many instances of how facts based on objective or controlled experiments forced old concepts to give way to new ones. Phlogiston (fire stuff) and ether (a medium permeating all space) are classical examples of such concepts.

This leads us to consider the role of objectivity in research. Every investigation is influenced by three conditions:

a. Accessibility of pertinent data for observation and experiment. For instance, data for outer space research are more accessible now than they were before the advent of radio communication.

b. Repeatability of observation of phenomena or events. Observations of eclipses of the sun are more easily repeated than those of novae and comets.

c. Possibility of treating subject matter objectively. Subjective views in connection with problems in the domains of social and economic research may hamper to a considerable degree the finding of the right approach.

The degree to which these conditions influence the direction of investigation varies from problem to problem. By comparing the types of problems arising in the twelve areas of knowledge, we find that the three conditions a, b, and c can be complied with to a lesser and lesser degree as we shift our attention from Area 2 towards Areas 12 and 1. Generally, the degree of possible objectivity (c) depends on the other two conditions (a and b), so that the more easily pertinent data are obtainable and the more readily they can be repeated, the greater becomes the possibility of objectivity. On the other hand, uncertain data and events difficult to establish or to reproduce lead to inferences biased by subjective opinions or beliefs. Hence research problems can be divided into three classes, depending on the relative possibility of objective treatment.

Class One encompasses those problems which involve to a large degree subjective views. These are the most intricate to deal with. For lack of an appropriate name, let us call them subjective problems. They usually concern desires and aspirations with which our imagination deals, hoping that one day they may be realized. To this class belong the problems raised by religious and philosophical ideologies.

Class Two contains problems which can be treated objectively to a considerable degree, but are still strongly influenced by the personal views of the investigator. Economic, political, and social problems belong to this class.

Class Three embraces all the problems in which objectivity can be the predominant attitude of the researcher.

Thus, the three classes of problems with their corresponding types may be schematically represented as follows:

Class 1.	Subjective		Dealing with religious and philosophical ideologies
Class 2.	Semi-objective	Type 1.	Dealing with economic, political, and social problems
		Type 2.	Dealing with problems in the early stages of a science
Class 3.	Objective	Type 1.	Phenomenological research
		Type 2.	Controlled experiment and precise measurement
		Type 3.	Setting up quantitative relations between phenomena leading to a theory
		Type 4.	General review and prediction of new facts deduced from theory

Leaving out Class One, as predominated by subjective problems, we will proceed to the other two classes.

Class 2, Type 1 problems involve phenomena to which controlled experiment and mathematical treatment can be applied only slightly or not at all. Nearly all economic, political, and social problems connected with community, state, national, and international relations are still of this type. Examples of urgent problems awaiting more adequate research are

1) overproduction, depression, and unemployment in industralized areas,
2) insufficient production and overpopulation in other areas,

3) balancing governmental control and pressure groups with democratic rule,

4) elimination of antisocial behavior, and

5) prevention of wars and revolutions.

Such problems can be approached by historical, descriptive, and statistical procedures. But because of the great diversity of factors involved and the equivocal statements of facts, together with the arbitrariness of definitions and emotional bias, logical methods do not prove very effective. They are generally counteracted by egocentric instincts, group interests, and aversion to change of the status quo.

Class 2, Type 2 includes problems for which the available facts are insufficient for a rational approach. Such situations prevailed in the earlier stages of development of budding sciences. From antiquity through the medieval ages and the Renaissance period mythological and magical approaches were used.

Historical evidence shows that by attempting to solve even exceedingly complex problems, new knowledge is being gradually gained. As new patterns of thinking evolve and inductive methods with controlled experimentation are applied, the understanding of essential factors is rapidly widening. Consequently, with time such problems tend to shift to Class 3 and gradually become the object of a more advanced type of research.

The following are examples of this type of problem:

1) remedies for and prevention of mental diseases,

2) diagnosis, therapy, and prevention of cancer,

3) problems of memory, creativeness, and learning, and

4) problems of aging--gerontology.

Class 3, Type 1 problems are encountered by a researcher when he comes across an entirely unknown phenomenon. He will start by establishing the conditions under which it occurs and by finding the conditions under which it may be modified in intensity, form, or character. This is the essence of phenomenological exploration, which later may lead to quantitative investigation.

Examples:

1) Deflection of a compass needle by electric current, observed by Oersted, opened the field of electro-magnetic phenomena.
2) Thermionic emission observed by Edison, but investigated by others, led to thermionics, a branch of physics.
3) A decrease of breakdown voltage observed by H. Hertz in a spark gap illuminated by ultra-violet light was the initial step which led to another new branch of physics--photoelectricity.
4) Discovery of X-rays by Roentgen while experimenting with cathode ray tubes revealed a new region of radiations.
5) Marie Curie's investigation of radiations and charged particles emanating from a mineral containing uranium resulted in the science of radioactivity.
6) The exploration of electric conductivity of crystals by Pierre Curie led to the discovery of piezoelectricity.

Class 3, Type 2 problems are those where there is no systematized knowledge relating to a phenomenon, but sufficient is known about it for proceeding with controlled experiments to investigate it qualitatively and quantitatively. The main feature of the investigation is quantitative observation based on controlled experiment and precise measurements.

Examples:

1) Mendel's investigation of hereditary characteristics in peas laid the foundation of a new science, genetics, applicable to plants, animals, and man.
2) Pasteur's classic work on fermentation opened a new field of knowledge, bacteriology, and led him to the conception of epidemics and their causes in plants as well as in animals and man.
3) Discovery of the ionosphere and its effect on the propagation of electromagnetic waves led to the science of ionospherics, a branch of geophysics.

Class 3, Type 3 problems are encountered when one tries to find the quantitative relations between two or more known phenomena, which seemingly belong to entirely different fields. Theoretical insight begins to predominate and makes use of bare as well as experimentally controlled observations in order to bring out the right interpretation and coordination of the facts.

Examples:

1) Faraday's researches led to electro-chemistry, electromagnetics, and magneto-optics.
2) Maxwell's theoretical investigation predicted and H. Hertz's experimental researches confirmed the existence of electromagnetic waves. These related optical and electrical phenomena.
3) Rumford's investigation of the heat developed by mechanical processes during cannon boring led to the concept of mechanical equivalent of heat and to the principle of conservation of energy.
4) Rutherford's discovery that nitrogen gas, bombarded by alpha-particles, produces hydrogen atoms confirmed his theory of radioactive disintegration and demonstrated the transmutation of elements.

Class 3, Type 4 characterizes a critical approach to a theory or concept from the point of view of logical consistency. The researcher must be interested in the disagreement between the theory and the facts, especially newly discovered facts. To remedy limitations of the theory, another theory or concept may be developed which will better coordinate the previous bits of knowledge and be capable of predicting new verifiable facts or phenomena.

Examples:

1) Copernicus' investigation of the motions of the heavenly bodies, following his criticism of the Ptolemaic Earth-centered system, led him to the discovery of the heliocentric

a problem of Type 2 of the same class, i. e., where the phenomenological exploration has already been done, our investigation will start with controlled experimentation B and follow the cycle B - C - D - A, etc. For a problem of Type 3, a theory will be the starting point, following a cycle C - D - A - B, etc.

These phases--A, B, C, D--are very general. From the point of view of zetetics, each of them includes subdivisions, as will be shown in a later section where the rest of the functions of research will be described.

These functional characteristics are common not only to all research problems of Class 3, but also to the many research tasks into which a larger research project may be divided.

Graphically the four recurring phases can be pictured as shown in Figure 7. 1. The spiral* represents the course of a problem as it proceeds through the four phases.

The upper part of the figure represents the spiral as projected upon a horizontal plane. The windings are shown here to occupy four quadrants, each corresponding to one of the phases. Starting from a point S, the course of the problem traverses repeatedly the phases of development A, B, C, and D in the direction of the arrows and asymptotically converges toward an ideal pinnacle P.

In the lower part of the figure, the spiral and its projected plane are shown in perspective. The upward movement from S to P is energized by new ideas which are checked by inductive processes of verification and investigated as to their consequences by methods of deduction. Each step increases the store of knowledge and extends the scope of experience, while each turn takes one to a higher vantage point and widens the outlook. Thus, it is useful to visualize research methods as a scaffolding helpful

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* In an article published thirty-five years ago this idea of a spiral was used to represent research in connection with the scientific method. See "Classification of Research Problems on Dielectrics" by J. T. Tykociner and E. B. Paine, Transactions of the Illinois State Academy of Sciences, Vol. 24, pp. 300-309, 1931.

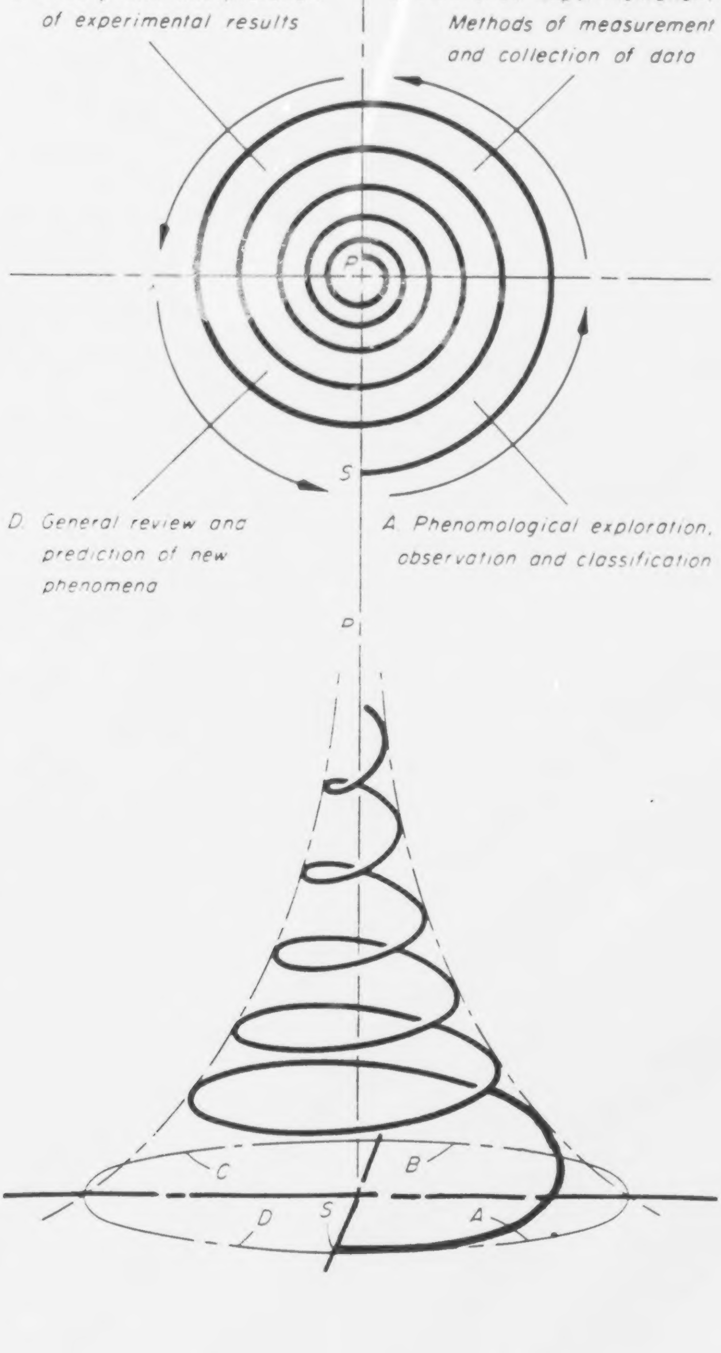
C. Theory and interpretation of experimental results
B. Controlled experimentation: Methods of measurement and collection of data
P
S
D. General review and prediction of new phenomena
A. Phenomological exploration, observation and classification
P
C
B
D
S
A

FIGURE 7. 1. RECURRENT CHARACTERISTICS OF RESEARCH

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in rigging up mental structures to reach higher levels of knowledge. If inspired by creative insight, an investigator may reach new levels which lead to an improvement, an invention, or a discovery. In a modern research enterprise such "mountain climbing" is generally carried out by a team of researchers so selected that each member takes up that phase of the investigation which is most suited to his particular abilities.

In a still broader historical sense such spiralling upwards symbolizes investigations carried out by generations of researchers, following each other throughout centuries in an attempt to solve a difficult problem.

For the sake of simplicity in presentation, only four phases of zetesis were shown in Figure 7. 1. A more detailed picture would include many more and show subsequent phases relating to the application and dissemination of results. These will be discussed later.

7. 7. Experimental and Theoretical Investigation

From the above discussion of recurrent zetesis, we can draw a few conclusions. One of them is that there are no distinct boundaries between phenomenological, experimental, and theoretical research. These types of investigation are linked together and support one another.

We know that originally research was carried on mostly by individuals. Each of them had to work through the above phases by himself; according to his abilities and inclinations, he emphasized one phase or another. When specialization became necessary, researchers gradually divided into two kinds: experimenters and theorists. They exchanged with each other the findings obtained from their particular activities. As members of a team, they became part of a community of interests sustained by private and public conferences, reports, and publications. They are thus involved in a zetetic process which includes phenomenological, experimental, and theoretical phases and results in more rapid progress.

The following example in low-temperature physics is typical of the way phenomenological, experimental, and theoretical researchers interact with one another. The first facts of electrical superconductivity were discovered in 1911 by Kamerlingh Onnes in Leyden by the observation that mercury suddenly loses its electrical resistance at -269° C. He was interested in the general equation of state and the general thermodynamic properties of liquids and gases. In many laboratories, systematic experimental researches were then undertaken because of their bearing on the theory of electrical conduction in solids. Since 1914 more than twenty elements and many intermetallic compounds have been shown to become superconductors, each at a characteristic transition temperature. In the course of these investigations, the surprising fact was discovered that copper and silver, which at normal temperature have the highest conductivity, do not become superconductive. Next, it was discovered that when a certain definite intensity of a magnetic field is applied to these metals, superconductivity vanishes. Further theoretical considerations led to the discovery that superconductors have perfect diamagnetism, i. e., magnetic induction is always zero in the superconducting state.

Attempts were also made, on the basis of hypothetical assumptions of interaction of electrons and ions within the conductor, to build a theory which would give an account of all the above facts. But they were only partially successful: further experimental exploration demonstrated the existence of a theoretically predicted "energy gap" between electrons in conducting and superconducting states. This provided a clue and a stimulus to more theoretical investigation. Not until forty-five years after Kamerlingh Onnes' discovery was a comprehensive quantum mechanical theory of superconductivity developed.*

7.8. Similarities of Approach in Basic and Applied Research

Another consequence which we can draw from an understanding of the zetetic process is that the recurring functions of research are similar for all problems. They are alike whether our problem is to develop mental and material tools for research; to improve techniques in agriculture, industry, medicine, or commerce; or just to enrich our store of knowledge and thus increase our understanding of the world around us.

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* J. Bardeen, L. N. Cooper, and J. R. Schrieffer, "Microscopic Theory of Superconductivity," The Physical Review, Vol. 106, No. 1, 1957, p 162ff.

Formerly we heard much of the distinction between "pure" and "applied" science. It has been said that "pure" science is prompted by curiosity, a desire to add new bits of knowledge to our intellectual heritage, and by the urge to understand how nature operates, while applied science is concerned only with the satisfaction of practical needs. But is not the satisfaction of curiosity a psychological need, since we suffer if we do not at least try to achieve that end?

Another argument for the division of research into "pure" and "applied" is the contention that applied science is the kind which produces immediate economic or social advantages. So far as we know from the history of science and technology, however, each new fundamental discovery has led to valuable applications and influenced many phases of human existence. It is a matter of initiative and the awareness of the various needs which determine the time which passes between discovery and application.

History also shows that progress in basic research actually followed technological development. The practical need for satisfying hunger by plowing, fishing, and hunting and of defending one's group against aggressors, bad weather, epidemics, etc. led to invention and ultimately to scientific development.

Later the scientists and philosophers who were engaged in experiments and speculations began to claim independence from any "practical" considerations. They rightly contended that their researches were more apt to bear fruit if they were not pressed to show immediate profit. So long as the interval between discoveries and their applications was large (twenty-five years or more), this division between basic and applied research had some sense. The two types developed without immediate interaction.

But the time interval between discoveries and their application is decreasing. Often applications are made as soon as a discovery is announced, and sometimes the mere prediction of a phenomenon inspires studies of possible applications of it. In addition, basic research has come to depend on complicated engineering devices, like cyclotrons, betatrons, and electronic computers which need technological research for their development.

Nowadays the works of theoreticians, experimenters, and engineers interact to such an extent that directly or through publications they simultaneously cooperate in advancing knowledge and technology. For instance, studies of the motions of electrons in electric and magnetic fields led to the construction of cyclotrons and betatrons. The latter were applied as a source of X-rays for metallurgical purposes and cancer treatment, for studies of the effect of bombardment of electrons on various materials, as well as for nuclear physics. The production of atomic power and an astounding number of applications of radioisotopes in industry, agriculture, medicine, and archeology resulted from these researches.

We may summarize by saying that from the point of view of zetesis the division of research into basic and applied is artificial, since the approaches and procedures in both are similar and because the development of fundamental knowledge requires the invention and design of apparatus and mental devices needed at every step in the basic as well as in the so-called applied research. Such distinctions mark only phases in the development of knowledge.

7.9. General Zetetic Process

The previous discussion of the recurring characteristics of zetesis was limited to those phases--A, B, C, and D--along which research problems proceed. As important as the outcome of those phases of research may prove to be when regarded as a contribution to a particular field of knowledge, they are only parts of a wider process which we call the general zetetic process. The latter aims not only to augment our store of knowledge, but also to lead to a consistent world view of the ways of life appropriate to develop and sustain a creative human society, as described in Chapter 2 and as indicated in Figure 2. 1. Therefore, following significant additions to our knowledge by discovery, invention, and innovation, the general zetetic process includes the application, dissemination, and study of various implications resulting from the growth of knowledge.

The following is a survey of the recurring phases of the general zetetic process. The letters to the left indicate the relationship between the functional characteristics See 1.6 of research and this process.

1) Inception, selection, or assignment of a problem.

2) Definition of the problem and location of its place in the system of knowledge.

3) Resolution of the main problem into specific subproblems.

4) Division of each subproblem into specific tasks.

A { 5) Collection and ordering of available facts pertinent to the problem.

B { 6) Search for interrelations among these facts.

Note: Whenever such facts were satisfactorily interpreted by means of an existing theory, the problem need not be followed further. If, however, existing theory cannot unify all known facts into a consistent system of interrelations, the next phase (7) is started.

C { 7) Formation of a hypothesis, eventually with revised or new concepts.

D { 8) Search for new facts suggested by the new hypothesis or theory, using direct or indirect observation or studying work of other investigators in the same field.

D-A { 9) Invention, design, and implementation of devices for controlled experiment. Devices may be mental or material.

B { 10) Systematic recording of data, especially if many instruments or other sources of information must be observed simultaneously, insuring that only one variable is changed at a time, or that mathematical interrelations between the variables are well known.

B

11) Collection and analysis of data (quantitative and qualitative).

12) Reduction of data to repeatable characteristics--facts.

13) Study of discrepancies between theory and the results of measurements.

14) Correction of possible sources of error.

15) Inclusion of the new facts thus established into the system of known facts.

C

16) Interpretation of new facts on the basis of previous theories.

Note: If phases 15 and 16 are feasible, the problem has been successfully solved, and further phases can take their course. Otherwise, a new research cycle will have to be initiated by a revision of the previous approach. A new cycle of phases from 1 to 16 will have to be followed. Possibly many cycles of research will have to be undertaken before creative activities will yield satisfactory results.

D

17) Critical review of the situation.

18) Prediction of new facts by deduction from the new theory.

19) Application of the new experimental devices or methods for scientific, technological, medical, and other developments.

20) Application of the new theory or other mental tools for furthering scientific, technological, medical, and other developments.

21) Application of the resulting new ways of research to advance zetetics.

22) Dissemination of results by

    a. publication
    b. lectures and teaching, and
    c. incorporation of new knowledge into existing stores of information (abstracts, card systems, microfilms, automatic retrieval systems, historical accounts, creativity reports, textbooks, etc.)

23) Study of resulting implications, especially
   a. philosophical,
   b. social,
   c. economic, and
   d. zetetic.

With each such cycle of the general zetetic process, knowledge will reach a higher level. New problems may then arise that will require a repetition of part, or even all, of the cycle. Even if the problem is not completely solved, the results may influence the course of human thought and open up new avenues of development.

What may appear as a limitation of the general zetetic process is that, while it is fully applicable to the problems of Class 3, it cannot be applied so well to problems of the first and second classes which we called subjective and semisubjective. The facts of these problems are so fluid and so influenced by subjective considerations that generalizations concerning them are most difficult to obtain.

Therefore, it must be admitted that problems in some fields of knowledge may at the present stage of development prove impervious to certain forms of approach, like experimental verification and mathematical treatment. Consequently, the solution of such problems may be delayed. Nonetheless, the rest of the general mental tools of zetesis remain the same in all classes of problems.

It need hardly be mentioned that the above described process as a whole is beyond the reach of any one individual. It is rather the task of the entire community of scientists, scholars, engineers, zetetists, and artists to participate in this process. But each individual researcher may be inspired by his knowledge of the existence of such a process involving all mankind. Moreover, by finding his place in the general scheme of activities and by realizing his role in this gigantic process of conscious evolution, he may be stimulated in his endeavors to contribute his bit to the enlargement of knowledge.

7.10. Zetesis as a Factor of Cultural Cooperation

With the beginning of this century, we started an accelerating process of zetesis which enables mankind to a greater degree than ever before to influence consciously its further development. We have advanced beyond the primitive stage when the shaping of our destiny was left to mere chance. In zetesis we are acquiring the means of struggling with blind and destructive forces and are gaining knowledge of how to steer clear of dangers and direct our future in accordance with our aspirations. Our combined activities can be made to converge upon furthering and promoting this evolution. They can be only briefly mentioned here. Some of these collective activities are as follows:

a. Improving methods of conserving the heritage of systematized knowledge and the objects of creative skills which mankind has already accumulated in
   - libraries,
   - archives, and
   - museums.

b. Devising improved methods of preserving, recording, and reproducing objects of artistic creation by photography, sound motion pictures and video tapes.

c. Systematically reviewing this heritage, as a function of the history of science and the arts, by means of
   - periodic recording of developments,
   - preparation of specialized bibliographies,
   - collection of materials for biographies of creative men, and
   - summaries of the activities of scientific societies and institutes.

d. Analyzing and synthesizing the results of creative endeavors, as a function of the philosophy of science and the arts, by
   - criticism of prevailing concepts and
   - integration of language, logic, mathematics, and information theory as tools of research.

e. Drawing up and maintaining inventories of all sciences, as a task of zetetics, for the purpose of
    finding relationships between sciences,
    discovering new areas of knowledge, and
    unifying all sciences into a coherent system of knowledge.

f. Selecting and formulating problems for research as a part of zetetics by
    preparation of catalogs of problems and establishment of their rational sequence for research, and
    searching for paths of least resistance which require minimum manpower and effort in the solution of particular problems.

g. Studying the conditions propitious for the advancement of knowledge as a function of applied zetetics, by
    designs for proper laboratories, observatories, medical and other research centers, and
    methods for selecting and training personnel.

h. Creating new knowledge by
    experimental and theoretical investigations in particular sciences, including zetetics,
    analysis of results,
    prediction of new facts and phenomena, and
    study of the processes of creativity and insight.

i. Applying new knowledge to
    artistic production,
    development of new techniques in agriculture, medicine, and engineering,
    invention of scientific and technical instruments, and
    promotion of public health and social endeavors.

j. Disseminating new knowledge by
    building more schools, colleges, and universities,

communication between researchers, artists, scholars, and statesmen,

publication of results of investigations,

lectures and preparation of educational motion pictures, and

provision of new materials, apparatus, equipment, etc. for research in other institutes.

Transmitting new knowledge to coming generations by revision, extension, and incorporation of new discoveries into the teaching programs of schools and universities and

searching among pupils for talents and developing their mental and manual skills for research.

1. Integrating progress made in all areas of arts and sciences, including the area of pronoetics, with the view of benefiting mankind by

the reduction of hunger, ignorance, sickness, boredom, frustration, prejudice, and hatred, and

elimination of all kinds of violence, especially in international relations.

In the general zetetic process all twelve areas of knowledge are considered. For instance, the application of new knowledge to the sciences of pronoetics is covered by phases 19 and 20, while the area of zetetics is taken up by phase 21 and the area of disseminative sciences by phase 22. Phase 23 is especially significant; it includes the philosophic, social, and economic implications of new knowledge. This phase has been grossly neglected in all the special methodologies known so far. But is this not the significant phase affecting the stability of the social structure? Wars and revolutions may be ascribed mainly to our neglect of appreciating fully the impact which the growth of the arts and sciences exert on the ways of thinking and living in an advancing society. An early systematic study of this impact would lead to a gradual adaptation of society to consequences of new knowledge and could thus prevent many a catastrophe which plagues humanity.

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These are the perspectives which present themselves from the point of view of zetetics. The accelerating pace of the general zetetic process which we are witnessing in our times poses serious questions as to our preparedness to meet tasks connected with the needs and implications of an expanding research activity. New laboratory buildings and more teachers are not all that we need. The impact of the new developments requires that the whole educational system be better adapted to the increasing importance of research.

GLOSSARY

Aspirational sciences: Sciences which embrace a large variety of ideological patterns reflecting the highest human aspirations.

Creato-motive force: The property of the human mind which tends to initiate zetesis.

Disseminative area of knowledge: A group of sciences dealing with mass communication and the transmission of knowledge from generation to generation.

Endogenous science: Any science which originates by the merging of parts of two or more basic sciences of the same area.

Exeligmology: An area of systematized knowledge which includes cosmogeny, evolution, and history.

General systems: A shortened term for General Systems Theory which refers to the formulation and derivation of principles valid for "systems" in general.

Heterogeneous science: Any science which stems from parts of two or more sciences related to two or more areas.

Homeostasis: The property of certain biological organisms to react to physical and chemical changes so that normal conditions of temperature, blood pressure, etc., are automatically re-established.

Homogeneous science: Any science which stems from one area and from only one of that area's basic sciences.

Hylenergetics:	The area of systematized knowledge which embraces matter and energy and their transformations.
Taxilogy:	A branch of zetetics concerned with maintaining an inventory of all the arts and sciences and with arranging it systematically for the purpose of unifying knowledge as a whole by means of a consistent functional system which facilitates the search for interrelations and gaps in knowledge.
Zetegeny:	That part of zetetics which treats the origin and evolution of the arts and sciences.
Zetesis:	The activity of investigation: research and all forms of creative endeavor.
Zetetic:	An adjective qualifying particular stages of creative endeavor, especially research.
Zetetic process:	A sequence of recurring phases of research activity and creative endeavor.
Zetetics:	An area of systematized knowledge concerned with research and artistic activities which lead to the growth of the arts and sciences.
Zetetist:	A person active in developing zetetics.

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ERRATA

PAGE 23: The footnote should read

Science and Sanity . . . Non-Aristotelian . . . .

PAGE 81: The fifth and sixth lines should read

. . . (the famous categorical imperative of Immanuel Kant)

PAGE 96: The entry "anthroporophy" near the bottom should be "anthroposophy."